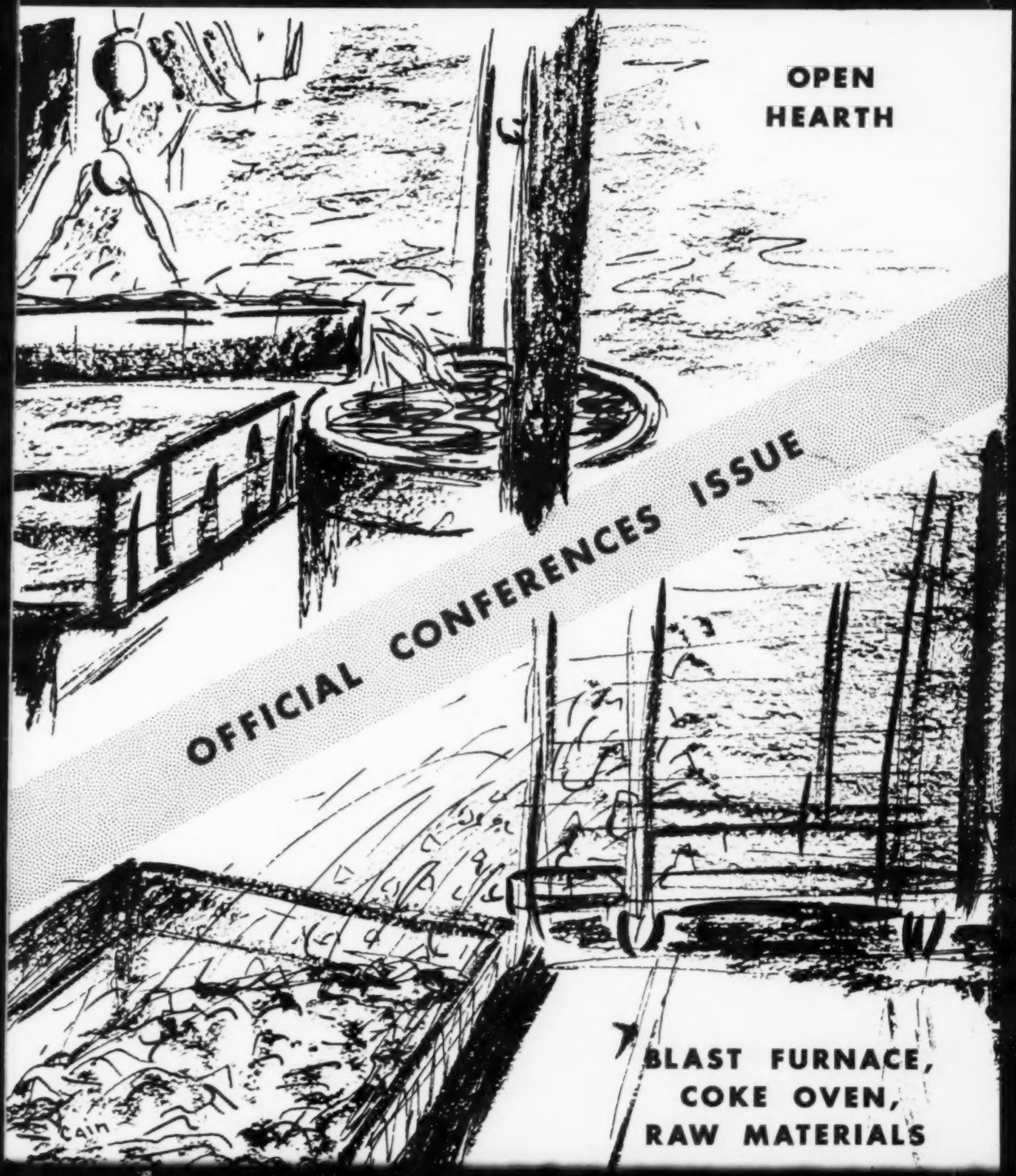
JOURNAL OF

METALS

APRIL 1961



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JOURNAL OF

METALS

Vol. 13, No. 4
April, 1961

COVER: Scenes familiar to all steel men—tapping molten steel and discharging coke from the oven—are depicted by cover artist David Cain in this issue dedicated to the 44th Conference of the National Open Hearth Steel Committee, and the Blast Furnace, Coke Oven, and Raw Materials Committee.

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personnel

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—MEN AVAILABLE—

Chief Metallurgist or Metallurgical Engineer, BS Met. Eng., age 48. Twenty years diversified experience in metallurgical and chemical laboratory supervision, application of ferrous and non-ferrous materials and processes. Recent experience in steel plant operations including melting, vacuum degassing and forging. Prefer Midwest or Southwest. M-2094-Chicago.

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Metallurgist-Manager, graduate, to run an electric furnace and electrolytic refinery for large tin smelter. Electro-chemical operation with Bolivian ores. Spanish or Portuguese desirable. Brazil, S. A. F40(a)

Metallurgists, (a) Sr., degree, with 8 to 10 years aluminum cold rolling and product development experience. $10-12,000 year. (b) Graduate, with 3 years research and development experience in aluminum production and fabrication. $6-$8000 year. Midwest. W21

Mill Superintendent with experience on pegmatites, to supervise small beryllium ore project. Transportation paid and housing provided. $8-$10,000 year. Brazil. F9380

Plant Metallurgist with 3 to 15 years experience, to develop and record methods for precious metal wire products, casting, extrusion, rolling, drawing, annealing, trouble shooting, complaint investigation. $7500 year up plus bonus. Connecticut. W9975

Plant Metallurgist, graduate, 25-40, with minimum of 2 years practical production experience in rolling of aluminum sheet or foil. Supervisory experience desirable. Duties will relate to quality and control of raw material, in process and finished products; also production methods, mill practices and general supervision. $9-$15,000 year. Excellent opportunity. East. W9960

Technical Products Sales Engineer to sell flocculents, mining and settling reagents. Some background as mill superintendent or mill engineer in ore beneficiation. $10-$12,000 year. New York City. W9931

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Research Metallurgist & Lecturer, MS or PhD, age to 45. Must be able to conceive research projects, supervise laboratory experimentation, teach in specialized field, guide graduate research, prepare research proposals and reports for research and education. $8000 up. Rocky Mountain area. C8264

Engineers, (a) Steel Plant Metallurgists, 2, graduates, for fully integrated small foreign steel plants producing a normal range of steel products. Should be qualified to set up and maintain quality control standards through all operations, including melting and rolling operations. Will be advisors to native plant chief metallurgist. One man for extended contract; one for short term to one year. $16-$21,000 year or per diem basis. (b) Open Hearth and Electric Furnace Operator familiar with all phases of small electric furnace operation in low alloys and carbon steels. Some basic Bessemer experience desirable. Should have good working knowledge of moulds, pouring practices, etc. $16-$18,000 year. South America. F37

Metallurgical Engineer, degree in metallurgy, to organize and conduct laboratory investigation on problems of corrosion, mass transfer and strength properties. Related problems in liquid material environments. Midwest. W24(b)

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The Proceedings of a Technical Symposium sponsored by the Nuclear Metallurgy Committee of the Institute of Metals Division, and the Titanium, Uranium, and Uncommon Metals Committee of the Extractive Metallurgy Division, The Metallurgical Society of AIME. San Francisco, February 16-17, 1959.

Edited by W. D. WILKINSON,
Argonne National Laboratory

The addition to these Proceedings of an introductory chapter on the metallurgy of plutonium and of an extensive annotated bibliography has made this volume of even greater value to metallurgists working in this particularly important field. Mr. Wilkinson both edited the Proceedings and provided the new material.

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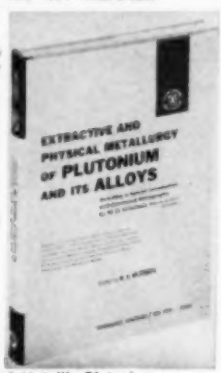
Introduction to Plutonium Metallurgy

EXTRACTIVE METALLURGY

- Alternative Routes for the Conversion of Plutonium Salts to Metal and Their Recovery Problems
- Calcium Reduction of Plutonium Halides to Metal
- Preparation of Metallic Plutonium
- Distribution of Plutonium and Selected Impurity Elements between Nitrate Solutions and Tri-n-butyl Phosphate
- The Preparation of Plutonium Halides for Fused Salt Studies
- Removal of Fission Product Elements from Plutonium by Liquidation



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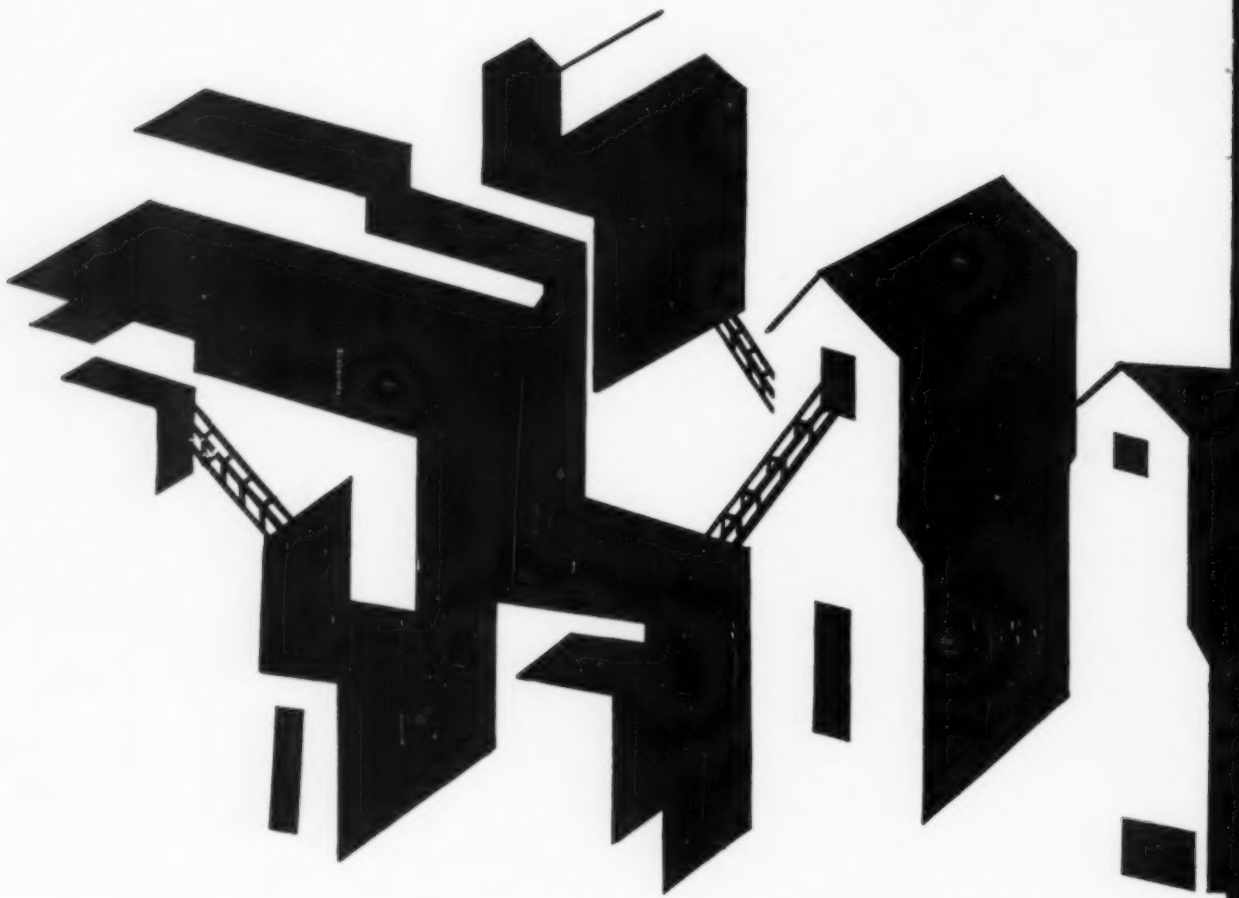
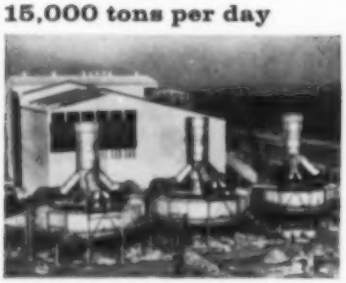


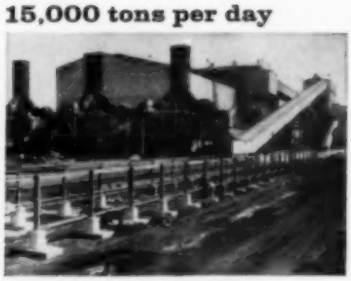
45% of the sintering capacity since 1955 has been

15,000 tons per day

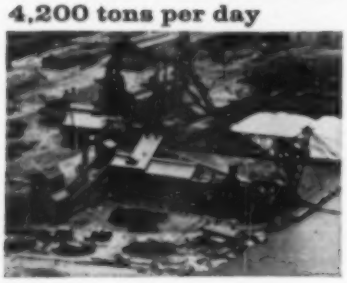


2,400 tons per day

15,000 tons per day

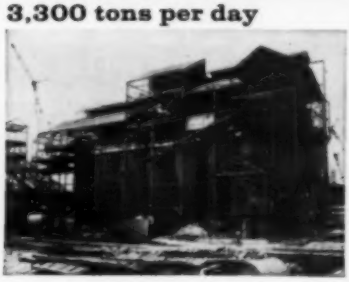


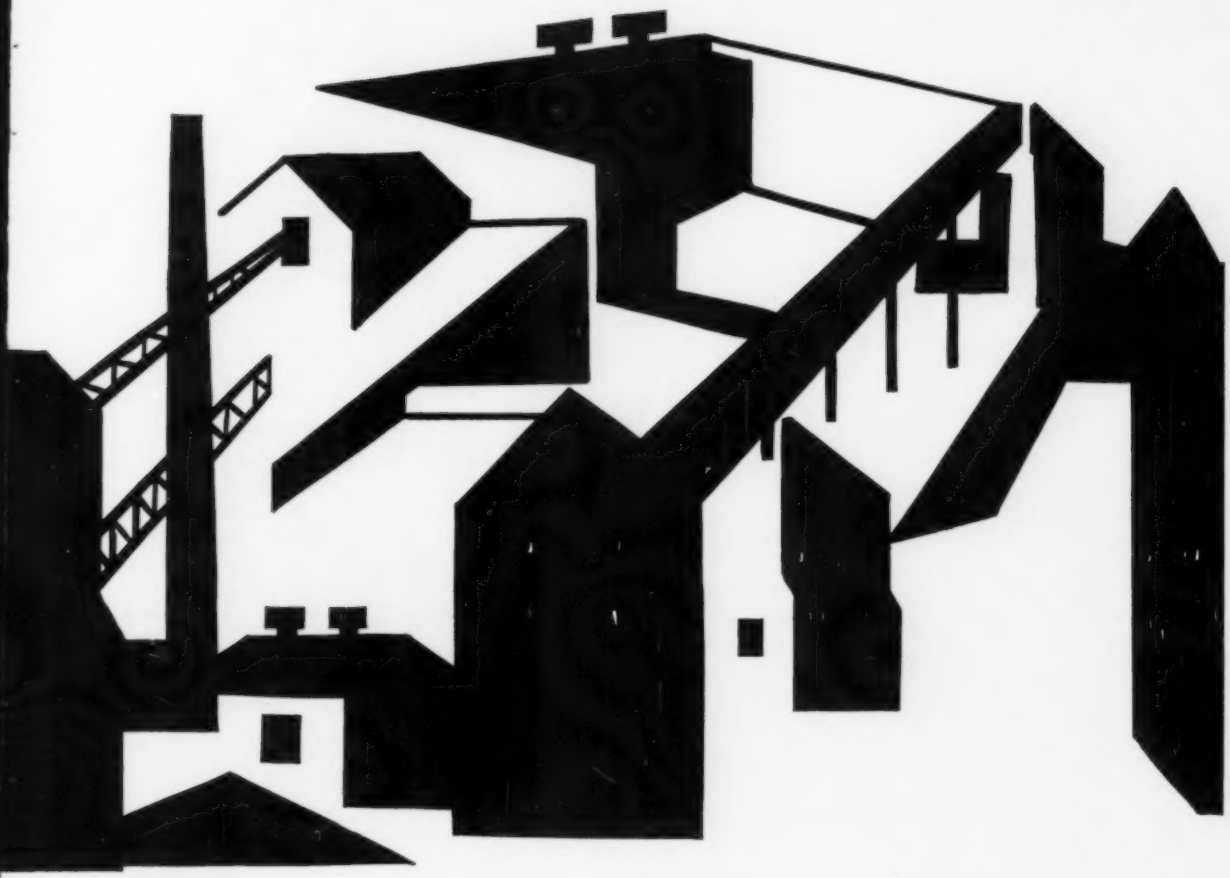
4,200 tons per day



6,500 tons per day

3,300 tons per day





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PROGRESS REPORT

STORA-KALDO OXYGEN STEELMAKING DEVELOPMENTS

In England, the Consett Iron Company Limited is installing two 110-ton Stora-Kaldo furnaces and Tube Investments Limited has announced plans to install one 85-ton furnace at their Park Gate Works . . . in France, Sollac (Societe Lorraine de Laminage Continu) has been operating their new 110-ton Stora-Kaldo furnace since April, 1960 . . . in Oxelosund, Sweden, another facility with 110-ton vessels will start production early in 1961 . . . in Domnarvet, Sweden, installation of furnaces of comparable capacity has been programmed.

The original 30-ton facility at Domnarvet, in operation since 1956, has passed the four-hundred-thousand-ton mark. Steelmakers from the United States have witnessed production, by this process, of a wide range of grades of carbon steel—1005 to 1095—without recarburization. The specified steel chemistry and tapping temperatures were met exactly. Slabs and ingots were shipped to the United States and processed into finished products, ranging from deep-drawing material to cutlery stock. Comments from ultimate users ran from "good" to "the best material we ever had."

These events and the facts detailed below are causing more and more steel producers to take a close, hard look at the Stora-Kaldo process:

FACT NO. 1. What is believed to be the largest single heat—143 tons—ever produced in a basic oxygen furnace of any type was produced by Sollac with its Stora-Kaldo facility. With normal production, heats of 130 tons and more are programmed.

FACT NO. 2. The ingot yield of virtually every heat at Sollac *has exceeded* 90 per cent since operations started.

FACT NO. 3. Capital costs for a Stora-Kaldo installation are comparable to or lower than competitive processes for equivalent capacity and conditions.

FACT NO. 4. The Stora-Kaldo process is inherently flexible in its ability to produce, within precise metallurgical limits, a wide variety of carbon steels on a heat-to-heat basis—not a "hit or miss" basis—without recarburization and at desired tapping temperatures.

FACT NO. 5. Based on current experience with European high phosphorus iron, refractory consumption with low phosphorus hot metal is estimated at approximately 24 pounds of refractory per ingot ton.

FACT NO. 6. The process can be operated with 96 to 98 per cent purity oxygen to produce steel having a nitrogen content of .003 per cent or less. A typical heat analysis using 99.5 per cent oxygen showed:

	Hot Metal	*Ladle*
C	3.6	.061
Mn	.330	.395
P	1.7	.015
S	.045	.011
N_2	—	.002

FACT NO. 7. Maximum oxygen flow rates currently are 8,500 cubic feet per minute and are being accelerated. Oxygen consumption is approximately 2,000 cubic feet per ton of steel when scrap is used for cooling.

FACT NO. 8. High percentages of scrap and ore can be used for coolant. The thermal efficiency of the process permits scrap addition of up to 50 per cent of total metallics charged. This will produce one and three-quarter tons of steel per ton of hot metal. If ore is used for coolant, approximately one ton of steel is produced per ton of hot metal.

FACT NO. 9. Size of gas cleaning equipment required is modest because carbon monoxide is almost totally burned inside the furnace. The exhaust hood is a simple water-cooled duct. The oxygen lance is a water-cooled pipe which projects through and is connected to the hood. The lance is automatically positioned as the hood is moved into place. Normal lance life is in excess of one thousand heats.

Engineering specialists are available to prepare economic and feasibility studies to help you evaluate the Stora-Kaldo process as it applies to your individual operations. Under United States and Canadian rights granted by Stora Kopparbergs Bergslags Aktiebolag, Sweden, Dravo can furnish complete design, manufacturing, construction and installation of Stora-Kaldo facilities, providing undivided responsibility for the entire contract.

For more information, write or phone Dravo Corporation, Pittsburgh 22, Pennsylvania, EXpress 1-2600.

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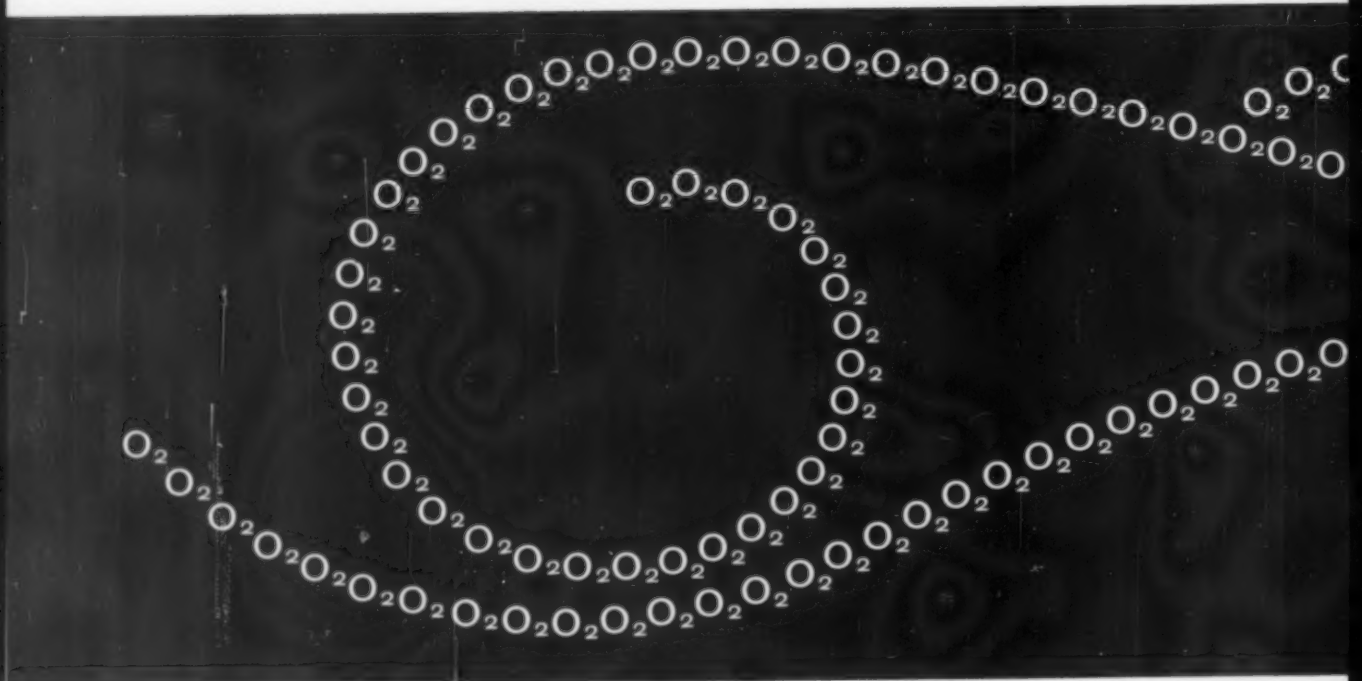

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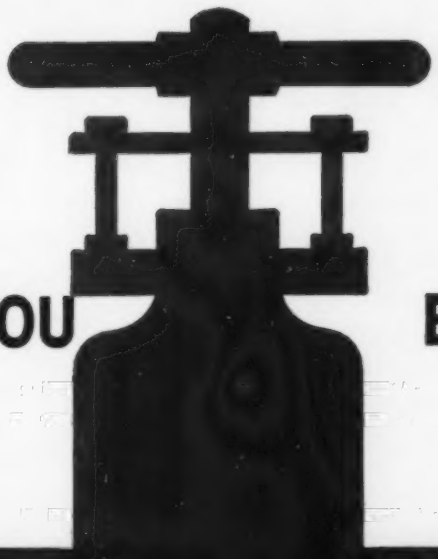

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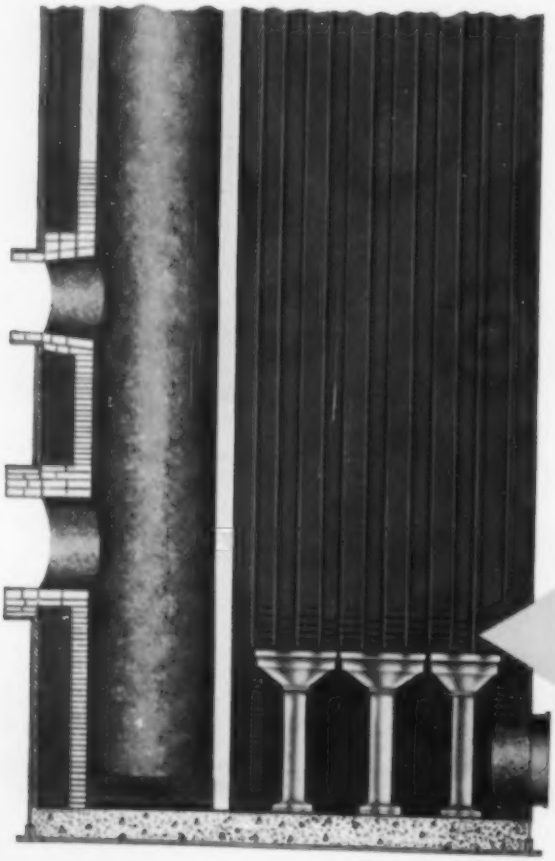

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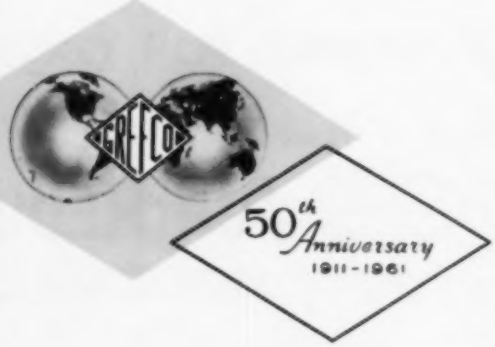

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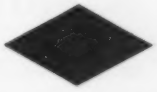

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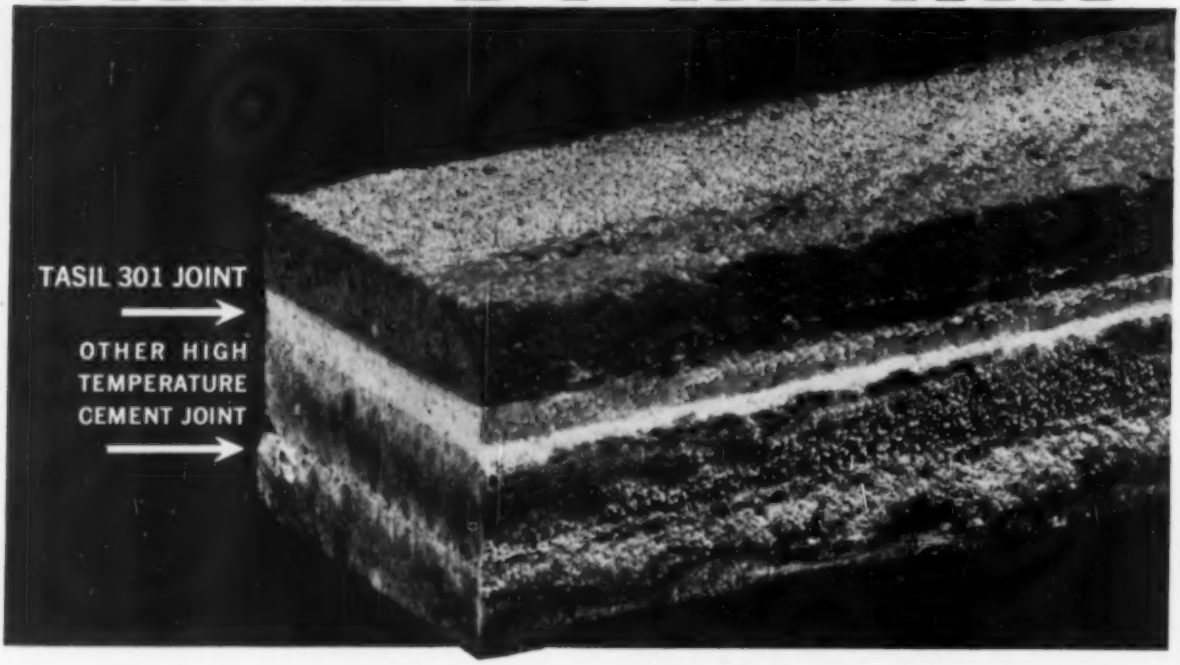

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Russian ore findings

Iron ore deposits totaling about 7 billion tons have been prospected in Turgai, northern Kazakhstan, according to Tass, the Soviet News Agency. An ore dressing combine, the Sokolovsko Sarbaisky, is being set up in Turgai. Its main quarry will produce about 17 million tons per year of iron ore. The quarry's first section has already been commissioned.

Two additional ore dressing combines will be built at Turgai before 1965. They will handle as much as 56 million tons of ore per year. It is estimated that the ore deposits adjoining the proposed combines will last for 160 to 170 years. The open cast method will be used to mine the country's cheapest ore, Tass reported.

Steel parachute

A stainless steel mesh cloth to be used for parachutes may be the answer to one of the problems facing US Air Force space exploration projects. Developed by the steel industry, the mesh is made of finely drawn stainless steel wire, and is currently being used in parachutes for space vehicles and filters to strain missile and space fuels. The new material may also be used in radar reflectors, antennas, auto roofs, convertible tops, seat covers, and decorative trimming.

The material costs $40 per yard and is so fine that it has 40,000 openings psi. The wire from which the mesh is made is produced by American Steel and Wire div. of U. S. Steel Corp. It is believed that the new material will supply the need for a material for space parachutes which can not only withstand the high heat of re-entry from outer space, but can also be resistant to corrosion and contamination resulting from the residuals blown off by the rocket motors of the space vehicle. Wire mesh parachutes will be placed aboard space vehicles to slow them down for re-entry into the earth's atmosphere and provide escape systems for occupants. Ordinary parachutes will not withstand the heat and shock strains at speeds above 1900 mph.

Pure tungsten castings

Oregon Metallurgical Corp. has made the first two castings of pure tungsten metal ever produced. Rated in the industry as technically pure, 240 lb of 98 pct W were shaped into missile nozzles for the US Government. Perhaps an indication of the magnitude of the accomplishment is that last year the US Bureau of Mines' Albany station achieved world-wide recognition when it produced the first molybdenum casting. The melting point of molybdenum is 4750°F and the melting point of tungsten is 6170°F.

Oregon Metallurgical Corp. is also producing 14 in. O.D., 60 lb vanadium rings which are believed to be the largest vanadium centrifugal castings commercially produced. Utilizing a vacuum-skull-casting process the company is also centrifugally casting other refractory metals such as columbium and molybdenum.

New oxygen plant

A $6-million facility to produce oxygen-nitrogen is under construction by Air Products, Inc. at the Sparrows Point works of Bethlehem Steel Co. Scheduled for completion by the middle of this year, the plant will produce 350 tpd of high purity oxygen and 450 tpd of nitrogen. The installation will produce oxygen and nitrogen in both liquid and gaseous form. The plant will be owned and operated by Air Products, and when added to the already existing oxygen producing plants, will increase Bethlehem's oxygen capacity by a factor of nine. In addition to the Sparrows Point requirements, the new plant will also supply Bethlehem's Steelton, Pa. plant some 100 mi away. Liquid oxygen will be transported by Air Products in over-the-road trailers and converted to gaseous oxygen at the steel plant site. The oxygen produced by the new plant will be utilized in open hearth injection, and the high purity nitrogen will be used for sheet steel annealing operations in the mill. Details of Bethlehem's open hearth injection practices can be found in this issue of JOURNAL OF METALS p. 300

Be-Cu alloy developed

Berylco 16C, a new alloy product said to have a combination of strength, ductility, corrosion resistance, and machinability previously unknown in the beryllium-copper alloy system, has been developed by the Bell Telephone Laboratories, Inc. and Beryllium Corp. The new alloy product is the result of a joint research effort begun in February 1956.

The material will soon be in commercial production at Beryllium Co.'s plant in Reading, Pa. Expected to be used for containing special electronic equipment, *Berylco 16C* is said to be almost completely nonmagnetic and so dense that it has withstood helium-penetration tests of 12,000 psi in special laboratory testing equipment.

New seal material

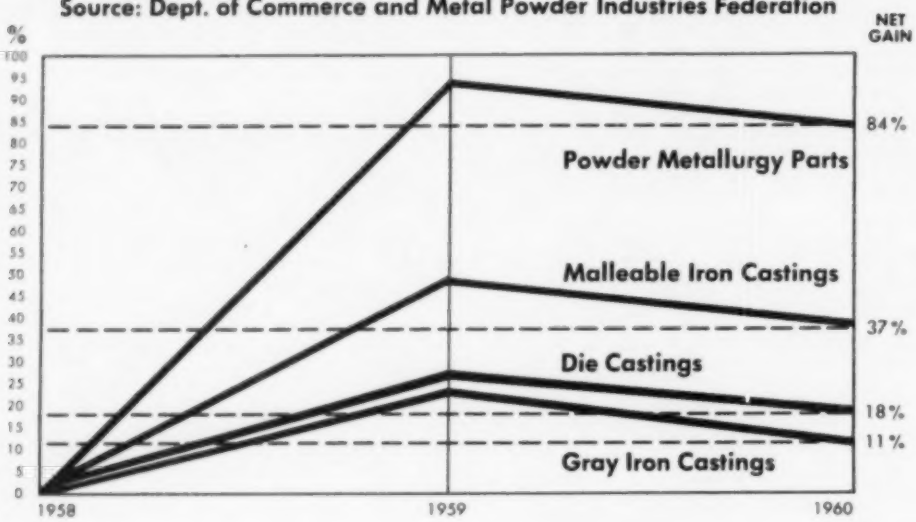
Armour Research Foundation has developed a new material for use in high temperature, high pressure static seals. It is a composite of two metals whose combined properties meet the requirements for seal applications in temperatures up to 1200°F and pressures of 5000 psi. The composites are made by impregnating a porous body of fiber metal, or skeleton, with a soft metal. The skeleton's resiliency combines with the softness and conformability of the impregnant to offer a seal material for almost any static high temperature-high pressure purpose. The metals are also corrosion resistant for use with chemicals, exotic fuels, or hydraulic fluids. The fiber metal skeletons are made by felting metal fibers, compressing them, and then sintering to form a bond between the fibers at each point of contact. The skeletons are usually made of molybdenum or stainless steel, with silver as the soft material. However, polymeric materials are currently under investigation as impregnants and have yielded good results in preliminary tests.

REPORTER

RATE OF GROWTH 1958-1960

(BASED ON TONNAGE CONSUMPTION FIRST 10 MONTHS)

Source: Dept. of Commerce and Metal Powder Industries Federation



Powder metallurgy outlook

The powder metallurgy industry seems to be moving ahead at a normal, if not increasing, pace despite a *tightening-up* by business in general, according to Kempton H. Roll, executive secretary of the Metal Powder Industries Federation. Powder metallurgy's continued growth is primarily a result of the fact that the method is becoming more widely accepted as a means of reducing manufacturing costs without sacrificing quality or performance of the finished product.

Surveys taken among metal powder producers showed that most are operating at about the same capacity as they were this time last year which is approx 50 pct of total capacity. Some are planning expansions ranging from 10 to 300 pct, and a majority of the producers are expecting *full recovery* before this summer. Optimism is high because iron powder consumption in 1960 reached almost 33,000 ton, only 2000 ton less than was consumed in the record year, 1959.

Powder metallurgy equipment manufacturers were found to be operating at about the same capacity as they were last year, and they also expect full recovery in the late summer or early fall. Compacting press sales reached about $3 million dollars in 1960 compared to $4¾ million for 1959. Mr. Roll stated that some association members indicated that by diversifying their markets as much as possible, they would be less apt to be effected by a slow down of a particular industry, such as the automotive industry.

Comparing the rate of growth of powder metallurgy parts manufacture with other competing industries, the Dept. of Commerce reports indicated that powder metallurgy parts usage showed a net gain of 84 pct during the two year period between 1958 and 1960 as against 37, 18, and 11 pct gains for malleable iron castings, die castings, and gray iron castings, respectively.

Research activity indicates that powder metallurgy is progressing and new techniques will further the number and quality of products produced by powder methods. Mr. Roll estimated that $2.5 to 3 million is being spent on research by private industry alone, and Federal activity in support of research is also substantial. Currently, between $1 and 2 million is being spent by industry and Government in support of powder metallurgy research in nuclear engineering, and another $500,000 is supporting investigations of dispersion strengthening techniques which hold considerable promise for the space program.

Looking ahead and discussing the immediate outlook for powder metallurgy in 1961, Mr. Roll predicted that the use of powder metallurgy parts would continue to surge upward despite, and perhaps even because of, the business economy. He felt that greater emphasis would be placed on the quality and performance and to a lesser degree, on the costs savings aspects of powder metallurgy.

Another US Al producer

Cerro Corp. (formerly Cerro de Pasco) has recently acquired the Union Pacific Aluminum Corp., of Los Angeles, Calif. The acquisition was accomplished through an exchange of 100,000 shares of Cerro stock. It is expected that Cerro will proceed with UPA plans for construction of a $10-million reduction plant near Longview, Wash.

In another project, Cerro will be one of four companies that will jointly build and own an aluminum hot-rolling mill near Oswego, N. Y. The proposed $30-million plant will produce aluminum reroll stock which will be purchased by the four owners—Cerro, Aluminium Limited, Bridgeport Brass Co., and Scoville Manufacturing Co.—for further fabrication at their respective sheet mills.

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Properties of Elemental and Compound Semiconductors

5 Sponsored by the Semiconductors Committee of the Institute of Metals Division, The Metallurgical Society, and the Boston Section of AIME. Boston, August 31-September 2, 1959

Edited by Harry C. Gatos

Contents

(Showing Part titles only: 21 papers were given, most followed by discussion.)
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6 **Flat Rolled Products II: Semi-Finished and Finished**
Proceedings of the Second Technical Conference Sponsored by the Mechanical Working Committee of the Iron and Steel Division, The Metallurgical Society and the Chicago Section of AIME, Chicago, January 20, 1960

Edited by E. W. Earhart and R. D. Hindson

Contents

Hot Machine Scarfing of Semi-Finished Carbon Steels
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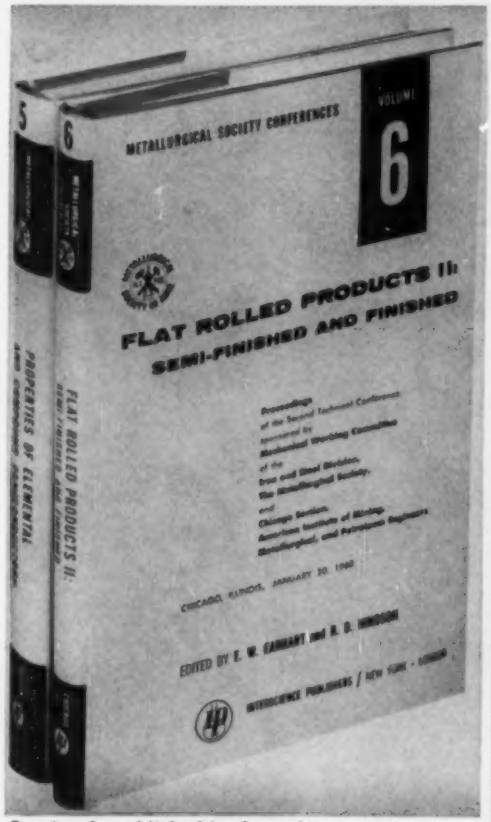

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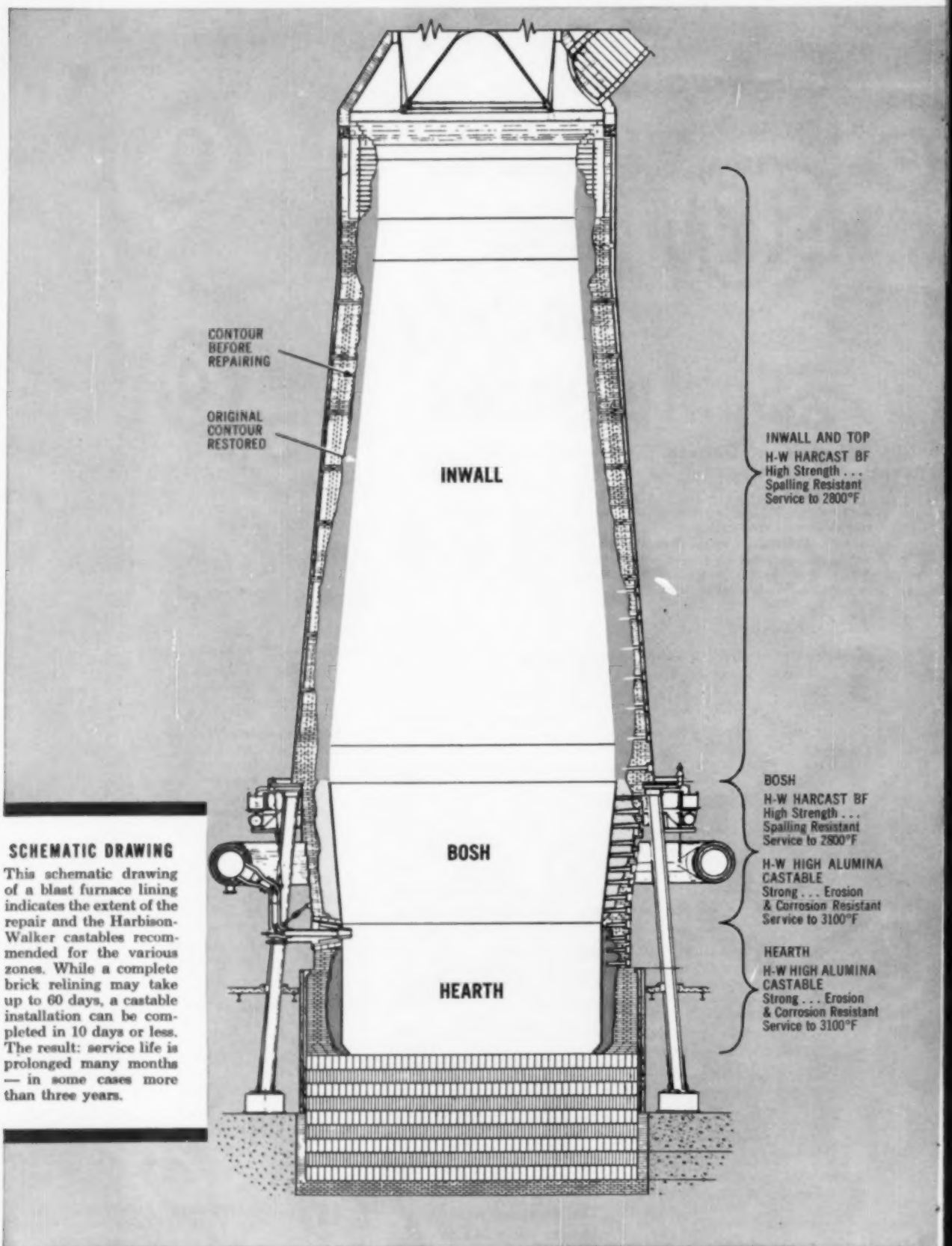

SCHEMATIC DRAWING

This schematic drawing of a blast furnace lining indicates the extent of the repair and the Harbison-Walker castables recommended for the various zones. While a complete brick relining may take up to 60 days, a castable installation can be completed in 10 days or less. The result: service life is prolonged many months — in some cases more than three years.

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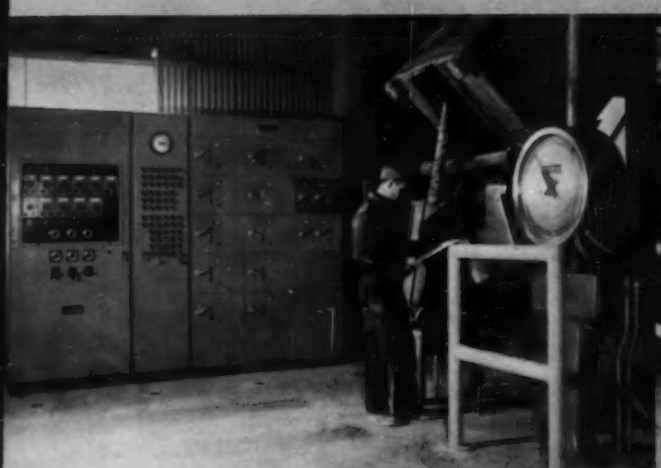

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letters to the editor

Phosphorus or Phosphorous?

A research administrator is apt to read with a blue pencil in one hand, since much of his effort is spent in editing reports by his staff. As such an enforced editor, I was about to blue pencil the paragraph heading on page 157 of the February 1961 JOURNAL OF METALS, which reads *Phosphorous and Ferroalloys*. The spelling of the first word looked like a typographical error.

Then I realized that this same spelling of the name of the element was used throughout the article. Since when has the name of this old element been spelled *phosphorous*? My school text books, Webster's Unabridged Dictionary, and all other references available to me agree that this word is spelled phosphorus.

Has AIME started on a campaign to change this old fashioned spelling, and should all good metallurgists support this stand as we do the Institute stand on tungsten or columbium? Or did FWS fail to blue pencil his own writing?

G. M. Butler
Director of Research
Gladding, McBean & Co.
Los Angeles, Calif.

[Sorry, we thought phosphorous had more colour and flavour than just plain phosphorus. Ed.]

☆ ☆ ☆

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Applications, requests for brochures, and general inquiries should be directed to R. E. Carroll, Engineering Summer Conferences, 126 West Engineering Building, Ann Arbor, Mich.

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editorial

The Age of Oxygen

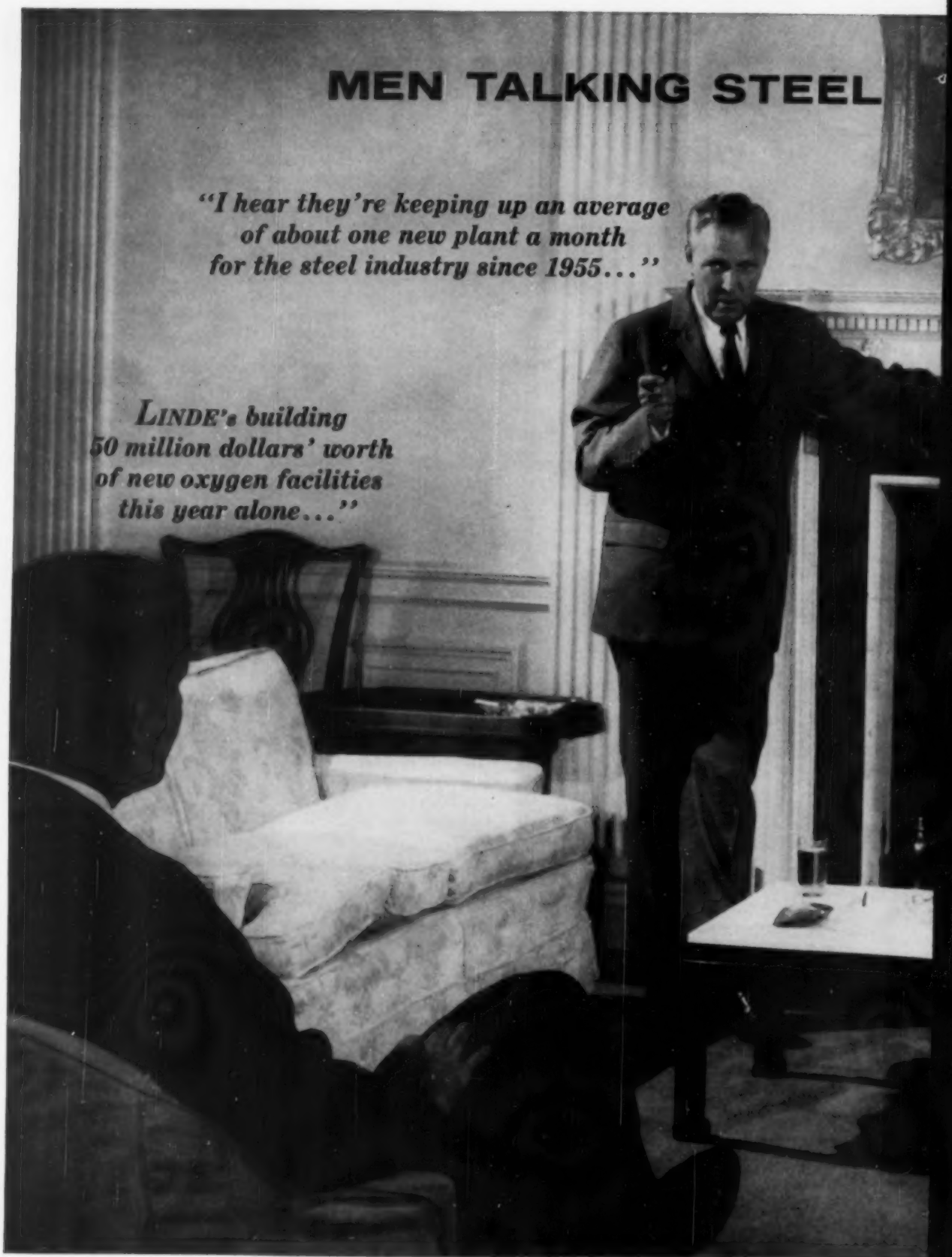
There was the bronze age, an iron one, and we could add quite a few more ages before arriving at the industrialized age of today, but as far as metallurgy is concerned, this is the age of oxygen—an age of revolution in pyrometallurgy, perhaps as far reaching as anything since the dawn of the blast furnace.

Metallurgists have long since realized that any process requiring air could be greatly enhanced by enriching the oxygen content of that air to the point of using oxygen itself. But for use in metallurgical operations, large quantities of oxygen would be required, and progress was at a standstill until tonnage quantities of low-cost oxygen became available. And even then it took some time to adapt thinking toward oxygen usage. There were a few apostles of oxygen usage during the late 30's and early 40's but blossoming came about with the development of the LD steelmaking process in Austria. Since then, there has been a complete reorientation of thinking, and oxygen has been *squirted* into blast furnaces, rotating furnaces, converters, and so forth. It has been used in lancing techniques for metal baths in ladles, open hearths, and electric furnaces.

Last month, the JOURNAL OF METALS gave account of oxygen moving into the ferroalloy industry to refine ferrochrome in a top-blowing technique. The refining of secondary copper by top blowing was also considered. In forthcoming issues, this magazine will take up the role that oxygen is playing in increasing the smelting capacity of the copper converter and reverbratory furnace, and lead smelting will not be neglected. But this does not end the list, and more will be heard of oxygen enrichment, jetting, and lancing.

In this issue we would call attention to the present keen competition that the open hearth is offering to the incursion of basic oxygen steelmaking processes. And here again the key is oxygen. First was the oxygen lance, and more recently the oxygen-fuel lance promises operating rates comparable with those of the LD process. Oxygen is completely revamping the thinking of open-hearth operators, and there is even talk of eliminating the traditional checker system. These changes are so profound that one author comments, ". . . within 20 years there may be little or no difference between the open hearth and the basic oxygen furnace . . .", and another states, ". . . in regard to future progress, the question may well be asked, how long are they going to continue to refer to this so-called open-hearth furnace as such?"

Pyrometallurgy—both ferrous and nonferrous—is undergoing a revolution as we move into the age of oxygen. FWS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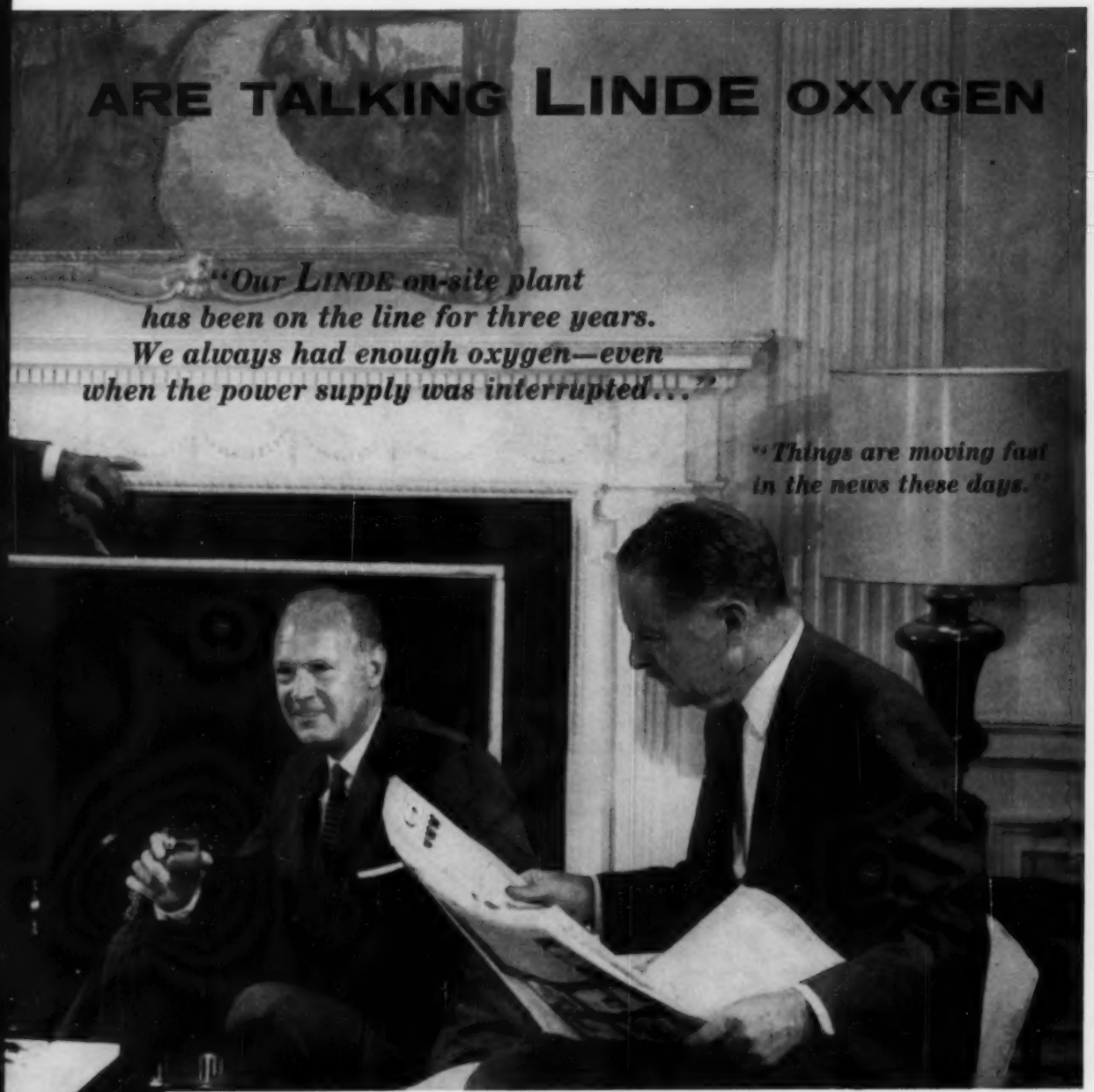
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Contents

Fabrication and Evaluation of Zircaloy-2 and Zircaloy-4 Tubing Used to Clad Uranium Dioxide and Aluminum-Plutonium Fuel	by R. C. Aungst, K. M. Haws, and P. L. Farnsworth
Mechanical Behavior of Cold Worked Nuclear Grade Zircaloy-2 Tubing	by H. H. Klepfer and C. N. Spalaris
Creep and Corrosion Behavior of Some High Strength Zirconium Alloys	by D. L. Douglass
Zirconium Alloys for Cladding High Temperature Fuel Elements	by R. K. Wagner, H. E. Kline, and D. I. Sinizer
Fabrication and Mechanical Properties of Aluminum Powder Metallurgy Products	by E. G. Kendall and W. H. Friske
A Review of Metal Hydrides for Nuclear Reactor Applications	by W. M. Mueller and J. P. Blackledge
Physical Properties of Yttrium Hydride	by E. S. Funston
The Zr-H System	by J. B. Vetrano and D. F. Atkins
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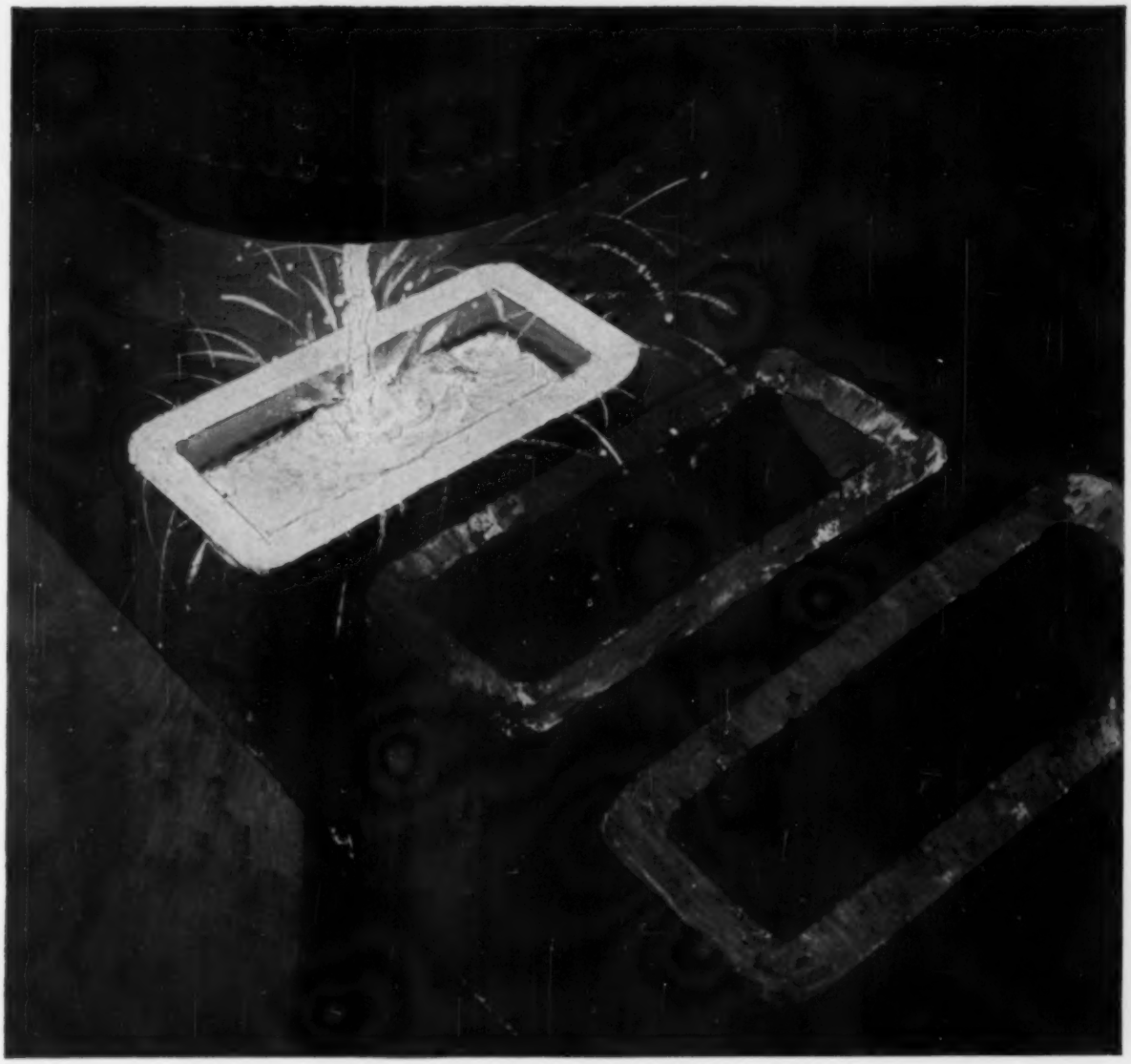

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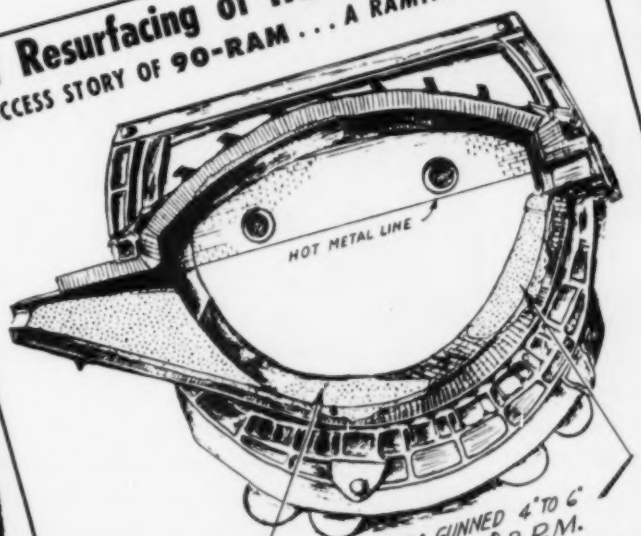

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The Optical Gas Maser (above) was first demonstrated at Bell Telephone Laboratories. Heart of unit is a 40-inch tube containing helium and neon. Interaction between gas atoms produces a continuous, coherent beam of infrared light that may one day be used in communications.

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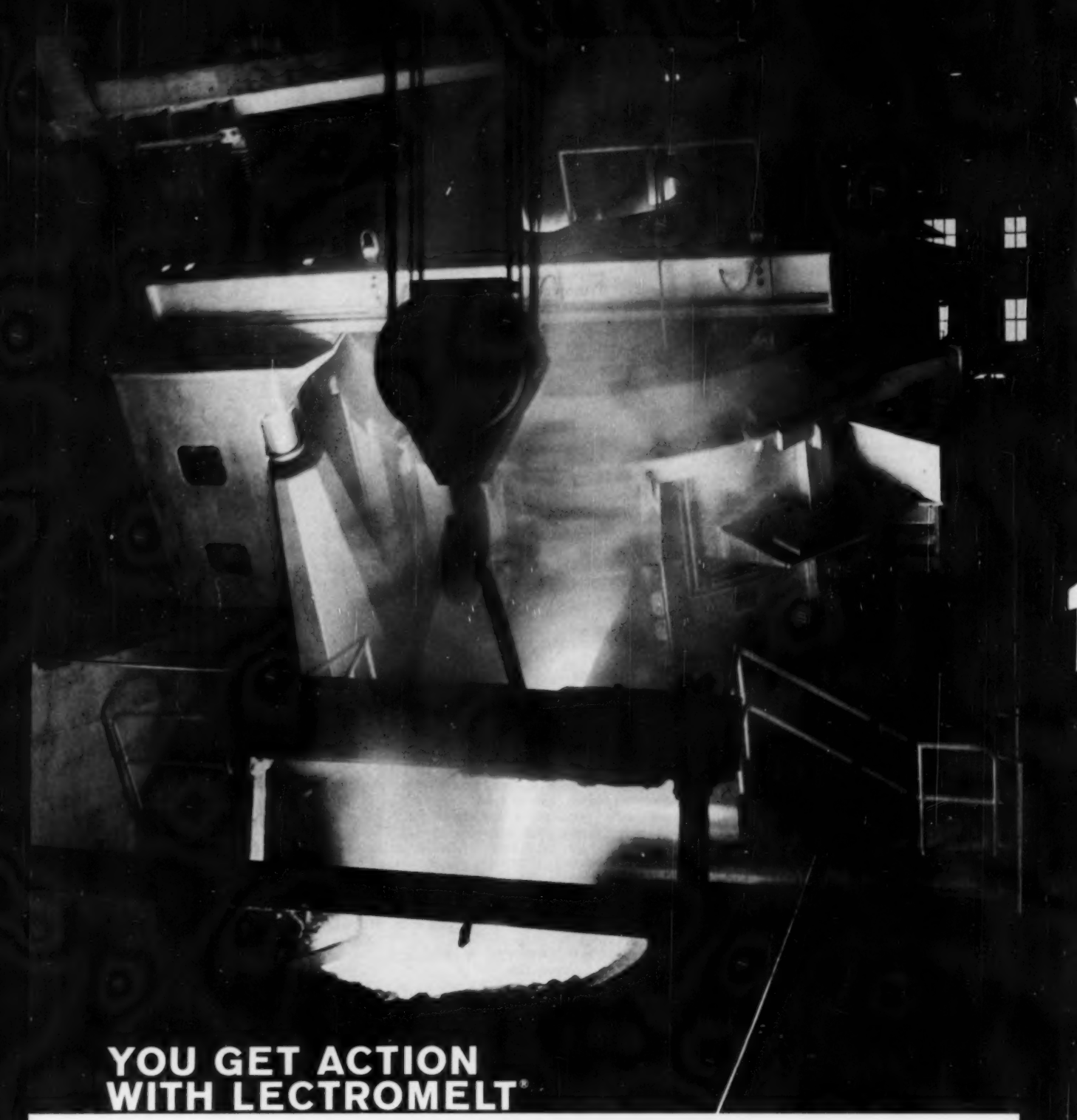

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Fundamental Principles of Powder Metallurgy

Fundamental Principles of Powder Metallurgy by W. D. Jones, Edward Arnold (publishers) Ltd., London, 1032 pp., 360 figures, 81 tables, $30.00, 1960. *Reviewed by Henry H. Hausner, consulting engineer.* •

W. D. Jones published his first book on powder metallurgy, *Principles of Powder Metallurgy*, in 1937. It was the first book in English on this subject, and for many more years it was the basic reference book for powder metallurgists.

Dr. Jones' recently published book *Fundamental Principles of Powder Metallurgy* is not just a revision of his first book, but an entirely new treatise for which the powder metallurgists have been waiting for many years. While it was still possible in 1937 to discuss all the then known principles of powder metallurgy in 199 pages, it is rather difficult to describe, in 1960, the *fundamental* principles alone, in 1032 pages. The author has, therefore, wisely omitted a description of industrial processes and the properties of products made by them, with the exception of where they could be used to illustrate the principles.

The book is divided into seven chapters.

Chapter I, 241 pages, deals with the manufacture of powder, which has been a specialty of the author for many years, and represents a complete textbook in itself. It starts with the reduction of oxides and continuous with precipitation from aqueous, gas, or vapor phases, electrolysis, and mechanical processing of solid and liquid metals. Special consideration is given to the preparation of tungsten and titanium carbides.

The chapter on pressure compaction (128 pages) is divided into three parts: uni-directional pressing, isostatic pressing, and hot pressing. The chapter includes also a careful description of the elementary principles of die and press design. The information on hot pressing is rather scanty. Extrusion as a compacting method is not discussed in this chapter, but at the end of the book.

It is the first time that a book on powder metallurgy contains information on pressureless compacting methods, and their discussion in Chapter III (15 pages), which is divided into sintering in a mold, slurry casting, and slip casting, will be welcomed by a great number of powder metallurgists.

Sintering, the most important process, is described in the 216 pages of Chapter IV. The author describes the history of sintering theories, and distinguishes between three periods: the speculative period prior to 1937; the simple theory period, 1937-48; and the complex theory period, from 1948 to date. Separate from the history of sintering theories, he reviews the history of sintering techniques. This most systematically written chapter deals with single and multiple component sintering, and emphasis is given in a space of more than 50 pages to the chemical reactions going on during sintering.

The largest chapter of the book (320 pages) is devoted to *The Attainment of Specific Qualities.* It deals with solid and porous materials and their properties, with electric and magnetic materials, bearings and friction materials, and diamond tools.

Chapter VI concerns *Continuous Powder Metallurgy*, (45 pages), and deals with powder rolling and extrusion, as well as with Emley's continuous pressing operation. A short chapter of methods of control of powders and green and sintered compacts concludes the book. A carefully prepared subject and name index will be helpful for the study of this excellent book, which is highly recommended to the specialist, and also to anyone who wants to enter the field of powder metallurgy.

Induction Heating Coil and System Design

Induction Heating Coil and System Design by P. G. Simpson, McGraw-Hill Book Co., Inc., New York, $11.50, 1960. *Reviewed by E. Buehler, Bell Telephone Laboratories.* •

This book is a handy reference text with a bibliography that is both extensive and complete. The low-frequency treatment is more complete than in some other texts.

Photographs are generously used, making for quicker communication between author and reader. This book could well be used as an aid in training people to operate induction heating equipment. Such supplementary reading would be particularly helpful where *set ups* might change frequently.

Certain items of interest are not mentioned in the text. Although these are not important in themselves, a book on induction heating would be more complete if it included such things as the latest information on unique coil designs—e.g. the double reverse turn pancake coil, the levitation types of coils, or the double cone shaped auto transformer types of coils, etc.—and a chapter devoted to the higher frequency induction heating covering the 5 to 120 megacycle per sec range.

Two minor errors were found in the crystal growing and zone refining sections. On page 201, the paragraph on the levitation method of silicon zone refining is misleading. Single crystals are obtained simply by the recrystallization of the silicon from the floating meet onto a single crystal seed of chosen orientation. A single crystal is not necessarily obtained by many passes through the coil.

On page 200, the description of germanium crystal pulling is not strictly correct. Impurities are usually added to the meet either prior to or during the growth, not by introducing them as part of the seed material.

The Corrosion and Oxidation of Metals

The Corrosion and Oxidation of Metals, by Ulick R. Evans, St. Martins Press, Inc., New York City, 1094 pp., $25. *Reviewed by M. G. Fontana, The Ohio State University, Columbus.* •

This book is indeed an encyclopedic work and should be of great value to all persons interested in corrosion and its mitigation. The author is the *Dean* of corrosion.

The book is very well organized. The first 18 chapters comprise the Qualitative Section and chapters 19-22 the Quantitative Section. The former is almost entirely free of mathematics and equations and is the more elementary portion. The quantitative section is more concerned with kinetics. Appendix I covers chemistry and Appendix II physical chemistry and electrochemistry for those readers with meager background in these areas. Each chapter is preceded by a synopsis which summarizes the chapter and shows its relationship to earlier and subsequent chapters. However, each chapter is more or less self-contained. Most of the many literature references are placed in or at the ends of paragraphs. The author index contains about 3000 names.

(Continued on next page)

The complete title is *The Corrosion and Oxidation of Metals: Scientific Principles and Practical Applications.* The book contains a tremendous amount of information and some information can be found in it on most any conceivable corrosion question or problem. The book should appeal to beginners, engineers, and also researchers interested in the pure science of corrosion.

This is not a revision of the author's earlier *Metallic Corrosion, Passivity, and Protection,* but it is an entirely new book. It presents Dr. Evans' own views and conclusions with summaries of the experimental work supporting them.

It is difficult to do justice to this monumental work in this brief review. The book is excellent reading and should be on every corrosion worker's reference bookshelf. The price of $25.00 is well justified.

Cobalt . . . Chemistry, Metallurgy and Uses

Cobalt . . . Chemistry, Metallurgy and Uses, edited by Roland S. Young, ACS Monograph, Series No. 149, Reinhold Publishing Corp., New York, 424 pp., $15.00, 1960. *Reviewed by F. R. Morral, Battelle Memorial Institute.* •

This Monograph replaces No. 108 of the ACS Monograph Series, published in 1948 and also written by Dr. Young. It has 398 pages of text versus 168 in 1948, and more than 1400 references compared with 260 in the earlier edition. The substantial increase in world production of cobalt and interest in the properties and applications are shown in this new Monograph.

The same general subject outline has been used, but the old chapters have been completely rewritten, some by Dr. Young. Contributors to the new edition are: Dr. A. G. Metcalfe—chapter on phase diagrams E. A. Nesbitt—magnetic, electrical, and electronic applications; and C. R. Whittemore—cobalt alloys in high-temperature, high-strength service. Other chapters of particular interest to the metallurgist and engineer are those on tool steels, cemented carbides, electroplating, and radioactive cobalt.

The chemist will welcome the comprehensive summary on coordination compounds by Professor D. H. Busch. In addition, there are chapters on history, occurrence, extractive metallurgy, chemical and physical properties, simple compounds, cobalt compounds in the glass and ceramic industries, catalytic behavior of cobalt, biology and biochemistry, and analysis of cobalt. The final 24 pages contain complete author and subject indices.

The reviewer believes that Dr. Young has accomplished the purpose of the ACS Monographs. He and his associates have provided the chemist and metallurgist with a thorough treatment of the state of cobalt through 1959; they provide the engineer and designer with useful data. In addition, the problems indicated should stimulate the student and scientist to further research.

The print and readability of the text is in the ACS Monograph tradition. Many metallurgists and materials engineers will find this book a *must* addition to their personal libraries.

* * *

Babylon To Birmingham, compiled and edited by H. G. Cordero and L. H. Tarring, Quin Press Ltd., London, about $8.50, 1960—This volume is an historical survey of the development of the world's nonferrous metal and iron and steel industries and of the commerce in metals since the earliest times. Part I of the book is *From the Dawn of History to the 19th Century;* Part II, *The London Metal Exchange in Peace and War;* Part III *More Historical Aspects;* and Part IV, *Stories of the Metal Trade.* This section contains such subtitles as *Attempts to Control the Copper Markets, The Queer Affair of the Hamburg Horseshoes,* and *The Sad Story of Harriet Lane.* •

Gold and Money Session is a 57-page booklet published by the Oregon Section of AIME. It contains the proceedings of a session which was presented at the 1960 Pacific Northwest Metals and Minerals Conference at Portland, Ore., April 29, 1960.

The booklet contains papers on *Review of Gold Production* by Donald H. McLaughlin, *Gold in the International Monetary System Today* by M. A. Kriz, *The Problem of Gold Convertibility* by O. K. Burrell, and *How to Obtain a Sound International Monetary System* by Philip Cortney. There is also a panel discussion and a *Summary* by Oscar L. Altman.

Copies of the booklet may be obtained for $1.50 each from the Department of Geology and Mineral Industries; State Office Building; Portland, Ore.

The Lead Smelting Mills of the Yorkshire Dales, by Robert T. Clough, Jowett and Sowry Ltd., Albion Street, Leeds, England, $12.00, 1961. The first part of the book gives previously unpublished information relating to lead smelting and mining methods as well as a chapter on the social life of the Yorkshire lead miner. The book is illustrated with 48 scale drawings, many of full page size. These illustrations include early original surveys, maps and reproductions from early mining works. Many of the methods set out by Georgious Agricola in his *De Re*

(Continued on page 280)

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National Open Hearth Steel Committee's Local Section Reports

C. B. JENNI

General Steel Castings Corp.
Eddystone, Pa.
Chairman
Eastern Section

Eastern Section

Through the courtesy of John Milos, vice president of the Phoenix Steel Corp., an interesting plant visit was made June 20, 1960. After visiting the steelmaking, rolling, pipe spinning, and bridge plant operations during the morning, the group were guests of their host at the Bull Tavern, famous since Revolutionary times.

In the afternoon, the Eastern section held their Fourth Annual Golf Party at the Plymouth Country Club. Arrangements were made by Golf Party Committee co-chairmen H. W. Potter and Hugh Kenworthy, Jr.

The Fourteenth Annual Technical Conference convened at the Warwick Hotel in Philadelphia on Friday, October 28. Registration for the meeting was 228.

Opening remarks by vice chairman R. R. Fayles included the announcement of the award for the Eastern section prize winning paper. The first prize of $100 was awarded to Spencer S. Bevins, Bethlehem Steel Co., Steelton, Pa., for his paper, *Maximum Hot Metal Charging at Steelton.*

The morning session, under the direction of program co-chairmen John J. Hannigan, Alan Wood Steel Co. and D. F. Brion, Bethlehem Steel Co., consisted of four papers. They were: *Oxygen Lance Experiments at Sparrows Point Plant* by R. F. Urban and D. F. Brion, Bethlehem Steel Co.; *Open Hearth Checkerboard Roof*, by R. C. Oswald, Sharon Steel Corp.; *Techniques in Rebuilding Open Hearth Furnaces* by C. F. Bessent, Bethlehem; and *European-Asiatic Trip—Spring, 1960*, by H. A. Parker, U.S. Steel Corp., Fairless Works.

Spencer Bevins presented his award-winning paper at the beginning of the afternoon session. The balance of the session consisted of a panel discussion on *Controlling Costs.* Frank Broglie, Bethlehem Steel Co., was moderator. Each member of the panel presented a short paper, as follows: *Yields* by John J. Hannigan; *Open Hearth Services* by Herbert A. Haas; *Refractories* by William Wilhelm; *Bottom Refractories* by Howard A. Parker; *Ingot Molds and Preparation* by Russ R. Jones; and *Cost Control Generalities* by George S. Baldwin.

A reception given by the Eastern Section Suppliers Assn. preceded the Annual Fellowship Dinner in the Ballroom. Music and entertainment, provided by Open Hearth Suppliers, featured a performance by the Men's Choral Group from U.S. Steel Corp., Fairless Works.

Plans for 1961 were formulated at a recent directors' meeting, held at the Engineer's Club in Philadelphia, Pa. The group will serve as host for the national meeting of NOHC in Philadelphia on April 10-12 at the Sheraton Hotel. The section's Annual Golf Party will be held at the Plymouth Country Club on June 26. The Annual Technical Conference has been scheduled for the Hotel Warwick in Philadelphia on October 20.

E. G. KONDAS

Republic Steel Corp.
Cleveland, Ohio
Chairman
Cleveland Section

Cleveland Section

Oxygen Use in the Open Hearth was the subject of the meeting held by the Cleveland section November 16 at the Saddle Inn at Avon Lake. A meeting January 18, at the Coach House in Cleveland featured discussions of *Open Hearth Pit Practice.* March 15 was Suppliers' Night, and the meeting was held at Pensano's Restaurant.

A report on basic refractories will be the feature attraction of the meeting which has been scheduled at the Coach House on May 17. The section's annual dinner dance will be held at the Lake Shore Hotel on June 17.

Newly elected officers for the next two years are E. G. Kondas, chairman; L. Svete, vice chairman; W. Nielson, secretary; and R. Minte, treasurer.

(MORE →)

A. T. HUBBARD

Youngstown Sheet & Tube Co.
Youngstown, Ohio
Chairman
Northern Ohio Section

Northern Ohio Section

The Northern Ohio Section held its annual Off-the-Record meeting March 10, 1960 at the Pick-Ohio Hotel in Youngstown. Three hundred seventy-eight members and guests attended the technical sessions which offered papers by J. Schosser, Sharon Steel Corp.; R. A. Francy, Weirton Steel Co.; R. P Hill, Sharon Steel Corp.; Frank Maron, Youngstown Sheet & Tube Co.; and J. W. Kirkpatrick, Youngstown Sheet & Tube Co. Co-chairmen for the meeting were F. J. Herman and John Beale. The after-dinner speaker was Irwin H. Such, editor of Steel Magazine, who discussed *The Outlook for Steel in the Competitive Sixties.*

The Squaw Creek Country Club was the scene of the section's golf party on June 8, with 331 members and guests attending.

The 1961 Off-the-Record meeting was held March 23 at the Pick-Ohio Hotel in Youngstown.

RALPH DUFFETT

Great Lakes Steel Corp.
Detroit, Mich.
Chairman
Detroit Section

Detroit Section

The Detroit section held a joint meeting on March 21, 1960 with the Detroit AIME Section. The meeting, which had *Degassing of Steel* as its subject, was attended by 132 members and guests.

On June 22, George Ferris, manager of the steel-making div. of Ford Motor Co., presented a program on the *Potentials of the Open Hearth.* (See page 298, this issue, JOURNAL OF METALS). The program was held in the Ford Auditorium with 142 people attending.

The annual golf party, held at the Dearborn Country Club on September 15, brought out 83 golfers and 175 for dinner. Prizes and trophies were awarded.

The 1961 program includes the recently concluded joint meetings with the Detroit AIME Section. The program, on *Slag-Metal Reactions,* was presented by Dr. John F. Elliott of Massachusetts Institute of Technology.

The Grosse Ile Golf and Country Club will be the scene of the 1961 golf party on June 20. A late October off-the-record session is scheduled, but final plans have not been made.

Section officers for 1961 are Ralph Duffett, Jr., chairman; George Ferris, vice chairman; Bruce H. Ramage, secretary; and John T. Brown, treasurer.

M. A. THOMPSON

Kaiser Steel Co.
Fontana, Calif.
Chairman
Western Section

Western Section

A paper on *Use of Oxygen in Open Hearth and Oxygen Steel Furnaces* was the feature of the Western section's first meeting of the year which was held November 15. Ray Armstrong of Linde Co., Newark, N. J., presented the paper. The section's second meeting was held December 21. Barney Etcheverry of Kaiser Steel Co., presented a paper on *Trends in Steel Consumption. Pressure Casting of Steel Car Wheels* was the title of a paper presented at the January 18 meeting by H. H. Hursen of Griffin Wheel Co., Chicago.

The section's fourth meeting was held February 15, with James C. Hicks, director of research, Kaiser Refractories & Chemical div., presenting a paper on *Better Refractories to Meet Steel Makers' Challenge.*

In April plans call for a plant visit to the Bethlehem Steel Co. in Los Angeles to see the new H-iron Process.

Officers of the Western section are Mitchell A. Thompson, chairman; Connie Forest, vice chairman; and Don McLeod, secretary-treasurer.

Buffalo Section

The Buffalo section's seventh annual golf party was held at the Wanakah Country Club on May 26 with 219 in attendance. The Open Hearth Suppliers' Committee provided an excellent lunch and cocktail party which, together with the golf tournament, provided a full day of good-fellowship. The entire registration attended the annual banquet, where golf prizes were awarded.

The Eleventh Annual Fall Meeting was held at the Hotel Statler-Hilton in Buffalo on November 15. The Lackawanna plant of Bethlehem Steel Company were hosts for the plant tour of their No. 3 Open Hearth Shop for this meeting.

Representatives from all major steel plants in the area covered by the Buffalo section contributed to the technical program. As a result there was high interest in the various topics and considerable discussion from the floor. A paper to be submitted in the *McKune Award Contest* entitled *Synthetic Bessemer Steel* and authored by Frank Sadler, open hearth metallurgist at the Buffalo plant of Republic Steel, was presented at this meeting.

F. G. GREGORY

Bethlehem Steel Co.
Lackawanna, N. Y.
Chairman
Buffalo Section

The registration for the Fall Meeting was 229 and dinner was served to approximately the same number of people at the annual banquet. Harry A. Morlock, who retired as secretary-treasurer of the Buffalo section after serving for seven years, was presented with a gift in appreciation of his long service to the section. The banquet speaker was Bill Mazer, sportscaster for Buffalo Radio and TV station WGR.

The luncheon and cocktail party at the Fall Meeting was again arranged by the Open Hearth Suppliers' Committee.

The date for the eighth annual golf party has been tentatively set for May 25, 1961. This party will again be held at the Wanakah Country Club.

The twelfth Annual Fall Meeting will be held at the Royal Connaught Hotel, Hamilton, Ontario, Canada on November 14, 1961.

The positions of C. E. Moyer and F. M. Jordan, chairman and vice-chairman respectively of the Buffalo section terminated as of November 15, 1960. The following officers will direct the affairs of the section during the year 1961: Frank G. Gregory, chairman; G. E. T. Cooper, vice-chairman; Harry A. Koegler, secretary-treasurer.

L. B. LINDEMUTH, JR.

Keystone Steel & Wire Co.
Peoria, Ill.
Chairman
Southwestern Section

Southwestern Section

The Southwestern section of NOHC held its annual spring meeting on February 12, 1960, at the Lennox Hotel in St. Louis, Mo.

After the technical session a suppliers' cocktail party was enjoyed before the Fellowship Dinner. Carl Henzelman, Granite City Steel Co., served as toastmaster, and Dr. Herbert True was speaker of the evening.

The annual fall meeting was held at the Sheraton-Dallas Hotel in Dallas, Texas on October 14, 1960. A plant visit was made to Lone Star Steel Co. at Lone Star, Texas on the day previous to the meeting.

Following the technical session an enjoyable hour was had at the suppliers' cocktail party. L. D. Webster, vice president, Lone Star Steel Co., was toastmaster and Robert Murphy, District Attorney, Nacogdoches, Texas was speaker.

L. B. Lindemuth, Jr. of Keystone Steel and Wire Co., has succeeded L. D. Yager as chairman of the section.

W. W. BERGMANN

Armco Steel Corp.
Middletown, Ohio
Chairman
Southern Ohio Section

Southern Ohio Section

The Twenty-fourth Annual Technical Conference was held September 23-24, 1960 in the Deshler-

(MORE →)

Hilton Hotel, Columbus, Ohio. M. Sample, Armco Steel Corp., and R. K. Thornberry, Acme-Newport Steel Co., served as co-chairmen for the morning operating session.

George Dahm, Linde Co, presented a paper entitled *Safety with Oxygen*. Papers on production and operating problems with roof lance furnace were presented by W. O. Richmond of Armco Steel Corp., R. L. Sigl, Detroit Steel Corp., and Gerald Curtis, Armco Steel Corp. *Method of Nozzle Setting* was the title of a paper presented by W. O. Richmond of Armco Steel Corp. Donald Saylor of Ford Motor Co., presented a paper on *Ladle Gunning*.

The Southern Ohio Section Awards Paper, *Bath Temperature Control on Oxygen Lance Furnaces*, was presented by Thomas D. Moore of Armco Steel Corp.

Co-chairmen for the afternoon session were O. V. Ireland of Armco and Eugene Allison of Detroit Steel Corp. R. K. Thornberry presented a paper on *Pneumatic Injection of Graphite in Open Hearth Bath*. Other papers included *Removal of Slag and Refuse from Open-Hearth Pits* by Don McCormick of Armco, and a *Progress Report on Basic Roofs* by C. Hesselman, Acme Newport Steel Co., Kenneth Ott, Detroit Steel Corp., and L. Yoder, Armco.

Registration for the session was 217, a record attendance, the previous high being 215.

The Fellowship Dinner, held at the Deshler Hilton Hotel, featured an address by the Rev. Lawrence Hall of St. Paul's Church, East Cleveland, Ohio. Toastmaster for the meeting was L. W. Moore, national chairman, NOHC.

The last annual golf outing will be held June 2, at the Elk's Country Club, Middletown, Ohio. The Southern Ohio section held its last conference in Columbus last year. Members have been invited to become affiliated with neighboring sections in 1961.

E. E. McGINLEY

U.S. Steel Corp.
Braddock, Pa.
Chairman
Pittsburgh Section

Pittsburgh Section

The two annual activities of the Pittsburgh section NOHC during 1960 were well attended and highly successful in all aspects. These functions were the spring golf party and the Fifteenth Annual Off-the-Record Meeting.

The golf outing and social dinner was held on Monday, June 13, 1960 at Mt. Lebanon Country Club and in spite of the inclement weather 172 participated in the golf affair. Dinner was enjoyed by 353 members and guests after which the entertainment committee, headed by H. R. Loxterman, distributed 55 prizes donated by the friends of the section.

The Fifteenth Annual Off-the-Record Meeting was held Friday, November 4, 1960 at the Penn Sheraton Hotel. All the local divisions of AIME joined with the Pittsburgh section NOHC in presenting all day technical sessions. These other divisions included the Coal Division, Petroleum Subsection, Institute of Metals Group and the Mineral Industry Group.

The general chairman of the meeting (AIME) was R. S. Redelfs while the general chairmanship responsibilities for NOHC were shared by A. G. Dean and F. R. Pullen.

There were 700 registrants for the technical sessions and judging from the active discussions which followed each presentation the program topics were pertinent and the information was presented excellently.

R. S. Crowell served as toastmaster of the Fellowship Dinner which was attended by 309 members, guests, and students. The suppliers' cocktail party which preceded the dinner offered a welcome respite from the day's activities.

The after-dinner program was highlighted by a talk given by J. R. Rohleder of the Bell Telephone Co. whose topic was *Project Mercury*. This informative speech covering communications as related to the missile program was enjoyed by all.

Among the guests of honor were J. L. Gillson, President AIME; Ernest Kirkendall, Secretary AIME; R. W. Shearman, Secretary NOHC; and C. M. Kay, Vice Chairman NOHC.

Officers of the Pittsburgh Section, NOHC, for 1960-61 are: E. E. McGinley, chairman; R. M. Barnhart, past chairman; J. N. Albaugh, vice chairman; S. D. Godleski, secretary; and J. H. Smith, treasurer.

Chicago Section

The activities of the Chicago section for the 1960-61 season consisted of the spring and fall technical evening meetings, the annual golf outing, and an all day off-the-record technical conference on March 8, 1961 at the Del Prado Hotel in Chicago.

The spring meeting was held May 2, 1960, at Phil Smidt's Restaurant, Hammond, Ind. The subject of the evening was *Trends Toward Larger Ingot Size and the Effect on Quality*. E. H. Reyer, superintendent of the open hearth, Wisconsin Steel div., International Harvester Co., served as technical chairman.

The Thirteenth Annual Golf Party was held at the Gleneagles Country Club on September 1. Attendance for dinner was 432, while 232 persons enjoyed the day playing golf.

On October 3, 1960, the Annual Fall Meeting was held at Phil Smidt's Restaurant. The subject of the meeting was *Utilization of Natural Gas in the Open Hearth Furnace*. Frank McGough, superintendent, power and fuel dept., Youngstown Sheet and Tube Co, served as technical chairman. Papers were presented by E. C. Rudolphy, U. S. Steel Corp.; R. McConnachie, Republic Steel Co.; P. J. Harrison, Continental Steel Co.; and R. D. Kahl of Inland Steel Co.

In March 1960, the Annual All Day Technical Conference was not held because the National Open Hearth Conference was scheduled in Chicago in April. In 1961 the meeting was resumed and was

M. E. NICKEL

International Harvester Co.
Chicago, Ill.
Chairman
Chicago Section

held on March 8 at the Del Prado Hotel. The program committee, with Al Kroner as chairman, arranged for the following papers: *The Effect of Basic Furnace Operations on Furnace Refractories* by C. J. Schiene and G. L. Michael of South Works, U.S. Steel Corp.; *Effect of Increased Open Hearth Furnace Productivity on Auxiliary Equipment* by F. P. Johnson, Inland Steel; *Steelmaking Practices in the Far East and Western Europe* by H. A. Parker, Fairless Works, U.S. Steel Corp.; *Use of Exothermic Side Boards and Hot Topping Large Slab Molds* by J. Mareta and R. Joseph, Inland Steel; *Open Hearth Quality Practices* by R. Groen, Wisconsin Steel; *Open Hearth and Blooming Mill Practices in the Manufacture of Seamless Tubing* by A. Sirel of Youngstown Sheet and Tube Co.; and the *Study of Oxygen Roof Lance Practices in the Basic Open Hearth Processes* by P. E. Dempsey, Gary Works, U.S. Steel Corp.

The officers of the Chicago section for the past two years have been Melvin E. Nickel, International Harvester Co., chairman; Albert M. Kroner, Inland Steel Co., vice-chairman; and William R. McLain, U.S. Steel Corp., secretary-treasurer.

New officers who will take office in April for the 1961-63 period include Albert M. Kroner, Inland Steel Co., chairman; William R. McLain, U.S. Steel Corp., vice-chairman; and Frank Todd, Republic Steel Corp., secretary-treasurer.

Events planned for 1961 are the Spring Technical Dinner Meeting which will be held on May 1 at Phil Smidt's Restaurant, the Annual Golf Outing at the Gleneagles Country Club on August 31, and the Fall Technical Dinner Meeting at Phil Smidt's on October 2.

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Blast Furnace, Coke Oven, and Raw Materials Committee Report

To describe the activities and accomplishments of the Blast Furnace, Coke Oven, and Raw Materials Committee, it is first necessary to define the period covered: it is not a calendar or fiscal year, let's call it a Conference Year. Our concern is with the Conference Year extending from Chicago to Philadelphia—April 1960 to April 1961.

Scope

Ironmaking and its related functions have blossomed in the last 15 years, and our Committee title, although quite long, becomes more and more restrictive. Therefore, our Executive Board has agreed upon the name *Ironmaking Committee*, and submitted it for approval to the Executive Committee of the Iron and Steel Division of The Metallurgical Society of AIME.

Although the definition of our Committee functions constitutes a presently-satisfactory scope, we have asked for representation on the ISD Scope Committee and tendered the name of R. E. Powers as a member. In the area of ironmaking, the Committee's scope promises to be changing continually.

Awards

At the April Conference, we have one very important award to present. Miss Katherine S. Lovell has edited our Proceedings for some years, but she now finds the pressures of the work to be too difficult. She is regretfully giving up her association with our Committee, and we have decided to present an award to Miss Lovell in appreciation of her long and excellent service.

Since Chicago and April 1960, our *Journal of Metals Award* has undergone significant changes:

1) The designation *Journal of Metals* is much too broad a designation for an award which recognizes an outstanding Conference paper. This name was originally applied because the cash award was contributed by the Journal, but this is now underwritten by our Committee treasury. Our next presentation will be of the *Ironmaking Conference Award*.

2) It has become increasingly difficult to appraise Conference papers properly and make the presentation during that Conference. Accordingly, recognition of the 1961 Award paper will be made at the 1962 Conference.

Many of the members of our Committee have felt the need for additional awards; we have established one, and we are still working on another: The Joseph Becker Award for distinguished contribution in the field of coal carbonization has been established. It is expected that the first presentation will be made at our 1962 Conference with suitable recognition at the Annual Meeting of The Metallurgical Society of AIME.

Publications

C. S. Finney and John Mitchell has completed a *History of the Coking Industry in the United States*. This is being published in the JOURNAL OF METALS commencing in this issue (see p. 285), and will later be incorporated into a volume on the history of iron- and steelmaking in the United States to be published by The Metallurgical Society.

The book on Ironmaking, History and Technology has been delayed, because of the difficulty encountered in attempting to stop the clock and proceed with an exposition of today's technology.

The 1960 Proceedings introduced a new policy of hard-backed covers. This has meant an increase in publishing costs, but a well-used reference book deserves protection.

Both the number and the cost of conference preprints is increasing each year. But when the suggestion is brought up that preprints be abolished, there are always a majority of loud objections. As a matter of fact, we have arranged to provide preprint envelopes this year, complete with a list of Proceedings advertisers.

Philadelphia Conference April 10-12, 1961

A 20-year review of Blast Furnace, Coke Oven, and Raw Materials conferences reveals changes, which, we hope, reflect accelerated changes in ironmaking. Years ago, the papers were by operators for operations, but today, while the operators are more in evidence, we have also added scientists, metallurgists, researchers, engineers, and theorists. To satisfy the various appetites, there will be nine separate sessions in Philadelphia.

The International Agglomeration Symposium—April 12-14 also in Philadelphia—judging by the well-organized preparations and the program, promises to be highly successful. Dwight C. Brown, program chairman for this conference is also secretary of our committee, and for that contribution we feel justly proud and wish them a most successful symposium.

Start making plans now to attend the 1962 conference in Detroit; it's going to be better than ever.

JAMES CHISHOLM
Chairman, Blast Furnace,
Coke Oven, and Raw Materials Conference

Acid Converter and Basic Oxygen Steel Committee Report

A. B. Wilder

The annual meeting of the AIME Acid Converter and Basic Oxygen Steel Committee will be held in conjunction with the forty-fourth annual conference of the National Open Hearth Steel Committee and the Blast Furnace, Coke Oven, and Raw Materials Committee at the Sheraton Hotel in Philadelphia on April 10-12, 1961.

The committee will hold special sessions on Monday morning, April 10, confined to the acid bessemer process. This will include the presentation of two technical papers and round table discussions of developments and problems relating to this process. On Tuesday morning, April 11, a session on the basic oxygen process will be held. This will include the presentation of several technical papers and a panel discussion of *automation*.

Of interest to members of the committee and others interested in the acid bessemer and basic oxygen processes will be the annual award for a major contribution to these steelmaking processes.

It was the unanimous decision of the award committee that the recipient of the award be G. M. Yocom, assistant to the general manager of Wheeling Steel Corp.'s Steubenville works. He has had wide experience in all steelmaking processes including crucible furnaces and puddle mills.

Educated at Lehigh University, Mr. Yocom worked between semesters from 1909 to 1917 learning the various iron and steelmaking processes, working in puddled iron shop, crucible steel shop, blast furnaces, acid, basic and duplex open-hearth shops, heavy forgings and rolling mills at Bethlehem. After service in World War I, Mr. Yocom was bessemer and open-hearth metallurgist at Jones and Laughlin Steel Corp. He was assistant superintendent of the open hearth and bessemer departments of the company's Aliquippa Works from 1930-37, when he joined Wheeling Steel Corp. as superintendent of steel works and rolling mills. He was assistant to the general manager in 1944 when he became a colonel in the administrative branch of the US Army. He served in China as chief of the coal, ore, iron and steel of the War Production Board for Nationalist China. After returning to the United States, he was engaged in 1946-47 in developing the use of oxygen in the open hearth, and in 1948 he assumed his present position with Wheeling Steel. He is presently engaged in technology of coal, coke, ore beneficiation and iron and steelmaking processes.

Preliminary plans are underway for an AIME International Basic Oxygen Steel Conference in 1962. This conference will be devoted to a discussion of the status of oxygen steelmaking throughout the world. It is expected that a number of foreign visitors will present technical papers. Plant visits will be arranged, especially for the foreign visitors. The conference, which will be held under the auspices of the AIME Acid Converter and Basic Oxygen Steel Committee, will probably be coordinated with one of the national AIME meetings. The date will be announced later.

During 1960 at the AIME Annual Meeting in New York, eight technical papers were presented at a seminar on the acid and basic converters and basic oxygen steelmaking processes. The first award of the committee was presented to Herbert W. Graham at a luncheon.

G. M. Yocom

In April 1960, the committee and guests visited the Kaiser Steel Co.'s basic oxygen steel plant at Fontana, Calif. A joint meeting was also held with the Western section of the AIME National Open Hearth Steel Committee. Another activity was an all-day technical session in Los Angeles on the acid converter and basic oxygen steelmaking. This meeting was held in cooperation with the AIME Southwest Metals and Minerals Conference.

The committee is also sponsoring the preparation of a chapter on basic oxygen steelmaking for the revised edition of the AIME book on *Basic Open Hearth Steelmaking*.

ARTHUR B. WILDER
Chairman, AIME Acid Converter
and Basic Oxygen Steel Committee

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BOOKS

(Continued from page 269)

Metallica of 1556 are compared to Yorkshire Dales smelting and mining practice. Copies are available from Robert T. Clough, Stoneleigh, Utley, Keighley, Yorkshire, England.

Theoretical Study of Equilibrium Diagrams in Quarternary Systems, (in French), published by the Institut de Metallurgie, 2 Avenue de Croy, Heverle, Louvain, Belgium. In two volumes, one containing about 170 pages of text, the other containing 79 plates. About $16.00, 1960. The work under review is destined to contribute to the theoretical study of equilibrium diagrams of phases in quaternary systems. The study is limited to study of liquid solid transformations. For these phenomena, a variation of external pressure is practically without influence.

A new mode of graphical representation of quaternary diagrams is utilized. This makes use of a model in four dimensions. The four constituents are measured parallel to the edges of a regular tetrahedron conforming to the classical method. The temperature chosen as the fourth coordinate is represented graphically with the aid of a fourth dimension. The diagram is projected orthogonally on three projection planes according to the classical method of descriptive geometry.

It is shown by simple constructions that it is possible to extract from these diagrams a series of isothermal sections as well as other sections defined by maintaining constant one of the elements composing the system. The diagram is thus a synthesis of all the partial diagrams of two or three dimensions. Later one can study systematically the equilibrium phenomenas which are encountered in the course of the liquid solid transformation of alloys of four constituents.

The last chapter gives a concise treatment of the problems of the graphical representation of equilibrium diagrams of more than four constituents.

Design Information on 5Cr-Mo-V Alloy Steels (H-11 and 5Cr-Mo-V Aircraft Steel) for Aircraft and Missiles (Revised), by R. J. Favor and W. P. Achbach, DMIC Report 116R, 22 pp., no price quoted, 1960—This revision includes the most recent design information on 5Cr-Mo-V aircraft steels. They are characterized by high strength:density ratio in the 1000°F range, sufficient hardenability to permit air quenching, and tempering temperatures of 1000° to 1100°F. Elevated-temperature design curves on short time ultimate tensile strength, tensile yield strength, compressive yield strength, ultimate shear strength, bearing ultimate strength, and bearing yield strength have been constructed, based on a number of published reports and papers.

Order PB 151072-R from the *Office of Technical Services, Dept. of Defense, Washington 25, D. C.*

Statistical Analysis of Tensile Properties of Heat-Treated Ti-4Al-3Mo-1V Sheet, by H. R. Ogden, G. H. Beatty, and A. E. Mace, DMIC Report 46I, 32 pp., no price quoted, 1960—This report is divided into two major parts. The first part examines the variance in tensile properties of Ti-4Al-3Mo-1V. The second part examines some of the correlations between properties and processing variables.

Order PB 151095 from the *Office of Technical Services, Dept. of Defense, Washington 25, D. C.*

The Effects of Alloying Elements in Titanium, Volume A—Constitution, by D. J. Maykuth, H. R. Ogden, and R. I. Jaffee, DMIC Report 136A, 232 pp., no price quoted, 1960—This report is the first of a series on the effects of alloying elements in titanium. Because so much information is available, it will be presented in several volumes. This first volume deals with the constitution of the binary and ternary a alloys. Subsequent volumes on the chemical, physical, and mechanical properties will be designated DMIC Report 136B, 136C, etc.

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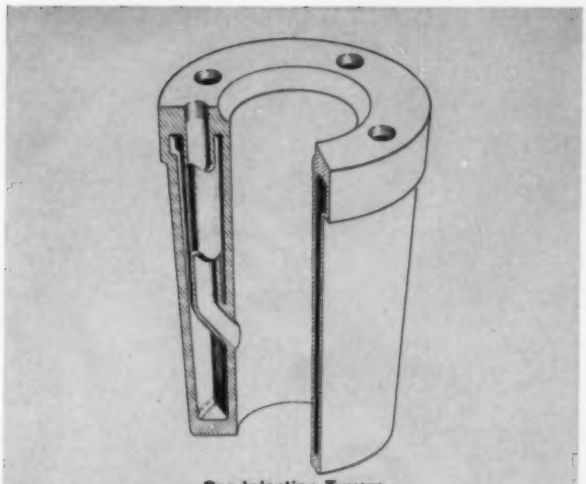

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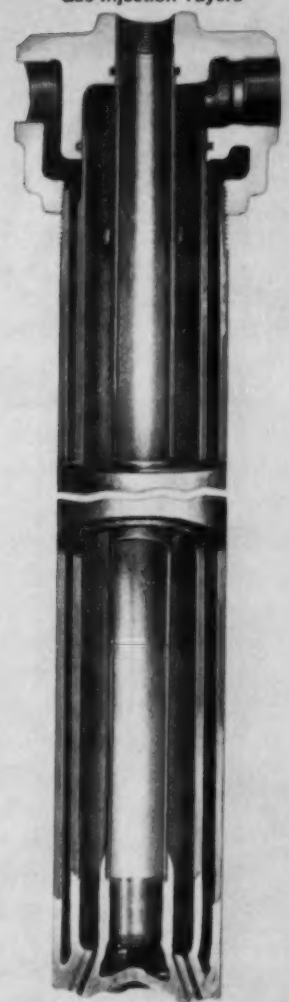

Oxyjet Open Hearth Lance — U. S. Patent No. 2,863,656

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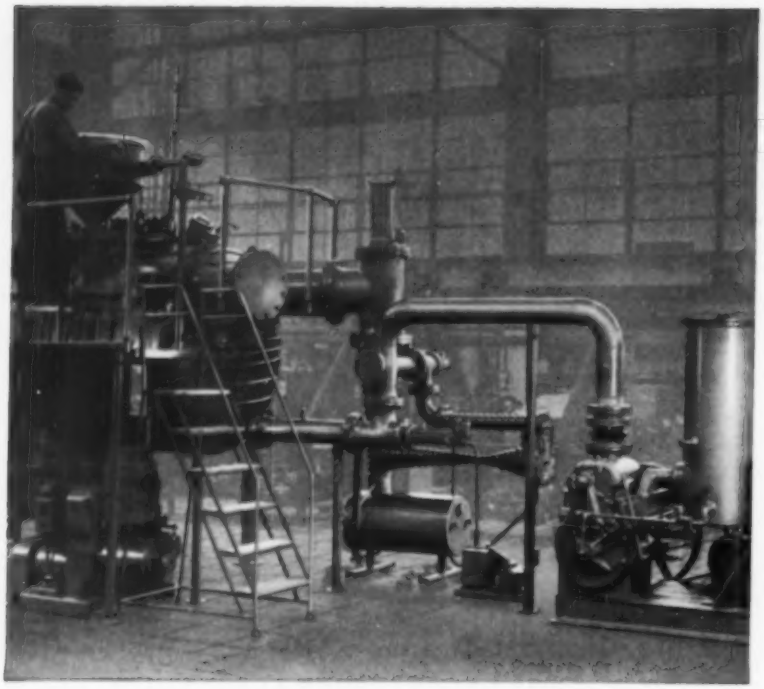

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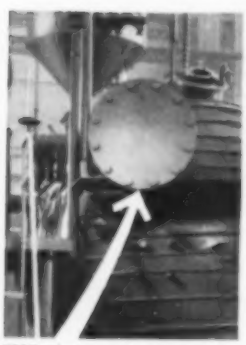

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personals

G. William Bauer has been promoted to technical sales manager of Stauffer Metals Co. He will have responsibilities in all areas of the company's sales and marketing in the field of electron-beam melted refractory metals and electron-beam furnaces.

Henry A. Bednarski has been appointed sales engineer in Basic Inc.'s furnace products div. He will be headquartered in Philadelphia. Mr. Bednarski was formerly with Harbison-Walker Refractories Co.

Leonard Bernstein has been named director of research and development of Alloys Unlimited, Inc., where he will supervise the development of new alloys for use in semiconductor devices.

Richard C. Cole is now executive vice president and general manager of White Pine Copper Co., a subsidiary of Copper Range Co. Mr. Cole was formerly vice president of both Vitro Chemical Co., and Vitro Minerals Corp.

Dilip K. Das has been named project manager at National Research Corp. Prior to joining the company he was head of the physical metallurgy section of Raytheon Manufacturing Co.

Eugene A. Gietzen is now chief metallurgist at Bethlehem Steel Co.'s Lackawanna plant. He had been assistant chief metallurgist since 1950.

Robert B. Heppenstall, president of Midvale-Heppenstall Co., has been awarded the American Society for Metal's William Hunt Eisenman Medal for service, devotion, and foresight in the metals industry.

Richard H. Lewin, vice president and director of Cerro Corp., has been elected president of the company's subsidiary, Cerro Sales Corp. He succeeds A. Russell Merz, who resigned in December.

John J. McGlone has been named vice president, sales, for the affiliated Cleveland-headquartered companies, Wellman Engineering Co. and McDowell Co., Inc.

Donald W. Meyer is now manager of marketing for cold finished and coated products for Sharon Steel Corp. He was formerly sales specialist for cold rolled products.

John K. Meyer has been appointed vice president and general sales

(Continued on next page)

manager of Corhart Refractories Co. He was formerly manager of metallurgical sales.

John E. Niesse has been promoted to manager of the process development department of Carborundum Co.'s research and development div. He was formerly supervisor of development engineering for the div.'s high-temperature materials project.

John Ross is now manager of the research and development department of Metals & Controls Inc. Since 1955 he had been with the central research laboratory of Texas Instruments, Inc., of which Metals & Controls is a div.

A. K. Schellinger has become research consultant in mineral and metallurgical processing for Tsumeb Corp. Ltd. in New York and Southwest Africa. He will be headquartered in New York until July when he will move to Africa. Mr. Schellinger was formerly with M. A. Hanna Co.

Charles W. Schuck has been named executive vice president of Braeburn Alloy Steel Corp., a subsidiary of Continental Copper & Steel Industries Inc. (CCSI). He was also named chief operating officer of CCSI's Braeburn Alloy Steel div.

Cyril Stanley Smith has been appointed professor at Massachusetts Institute of Technology effective June 1, 1961. He will divide his interests between metallurgy and the history of science and technology, being associated with the Metallurgy and Humanities departments. Dr. Smith is currently professor of metallurgy at the University of Chicago.

Ernest B. Snyder has joined Phoenix Steel Corp., as open hearth superintendent. He was previously refractories engineer with Wheeling Steel Corp.

Watt W. Webb has been appointed assistant director of research and **Roger L. Pilloton,** manager, extractive metallurgy of Union Carbide Metals Co. Prior to their present promotions, Dr. Webb was coordinator of the fundamental research group, and Dr. Pilloton was technical supervisor.

M. P. Weigel, director of operations of Aluminium Limited, has been elected a director of the company. He has been active in the aluminum industry for 36 years.

Joseph Zimmerman has become a consultant with Miles Metal Corp., of New York. Dr. Zimmerman recently resigned as editor-in-chief of the Daily Metal Reporter, a position he had held more than 40 years.

J&L

STEEL

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Research and Development Department
JONES & LAUGHLIN STEEL CORPORATION
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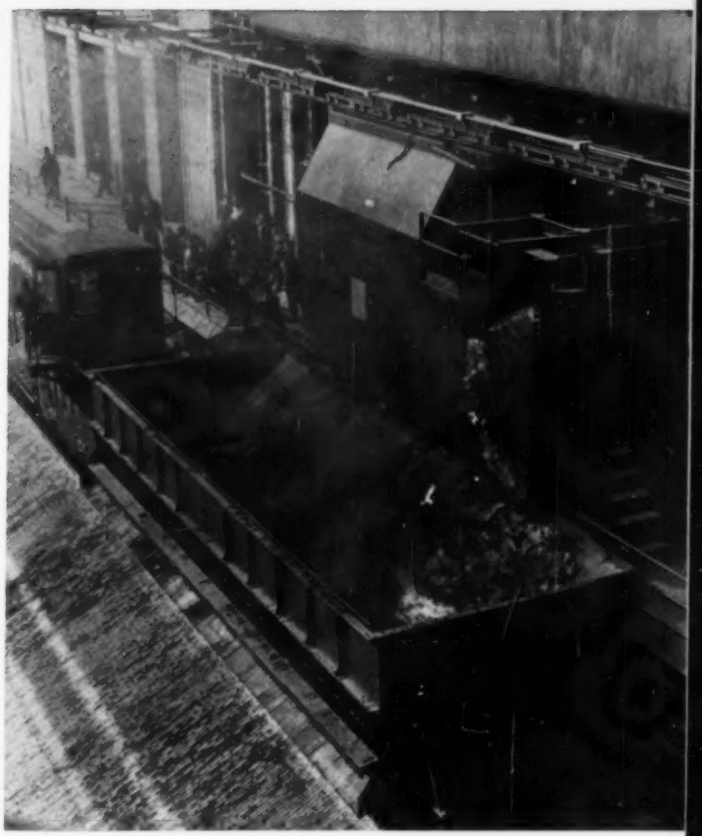
HISTORY OF THE COKING INDUSTRY IN THE UNITED STATES



First of a four-part article

During the past several years JOURNAL OF METALS *has presented articles on the history of all phases of iron- and steelmaking in the United States. This comprehensive history is the last of these articles. At a future date, The Metallurgical Society anticipates publishing all of these articles in one volume on the History of Iron- and Steelmaking in the United States.*

by C. S. Finney and John Mitchell

There is no field of human thought or endeavor which does not owe much to the past. Yet, surrounded by the prodigious scientific and technological achievements of our day, it is all too easy to forget the extent to which we have stood *on the shoulders of giants.*

The coking industry of the United States is now a little more than one hundred years old. As with the American nation itself, the earliest beginnings of the industry owe a great deal to British influences, and its development owes much to those influences of continental Europe. No serious contribution to the history of coking in the United States can be written, therefore, which does not mention the work of the pioneers of the Old World.

It is believed that the use of metallurgical coke dates back to antiquity. The fact that certain coals would soften under the influence of heat to yield a porous solid was known to the ancients of China and India, where a very crude coking operation was carried out by simply setting fire to piles of coal. After active combustion had started, turf or wet straw was used to seal off the pile. The coke obtained was used to forge iron and steel implements and weapons.

Perhaps the earliest reference to the coking phenomenon is to be found in the writings of Theophrastus, pupil of Aristotle. In his *History of Stones,* which was written in or about the year 371 B.C., there appears the following observation. "But the Lipara stone empties itself, as it were, in burning and becomes like the pumice, changing at once both its colour and density; for before burning it is black, smooth and compact. . . . Certain stones there are about Tetras, in Sicily, which is over against Lipara, which empty themselves in the same manner in the fire." The first comparatively modern reference to coke is to be found in a recommendation for carbonization made in 1584 by Julius, Duke of Braunschweig-Luneberg, owner of the Hohenbuchen mine in the Harz district of Germany. In 1587, Sir Francis Willoughby of Wollaton, England wrote: "There are twenty rooks broughte into charcoal and laid up in store." A rook of coal was equivalent to some 25 tons, and the coking would probably have been carried out in a manner similar to that used for the production of charcoal. In 1589, Thomas Proctor attempted to carbonize coal, and in the year 1590 an English patent was granted to John Thornborough, Dean of York, in order that he might "purify pit coal and free it of its offensive smell". Sir Robert Cecil (1595), Robert Chantrell (1607), Simon Sturtevant (1611) and John Rovenzon (1613) were all granted patents for the use of coal or coke

C. S. FINNEY and JOHN MITCHELL are with Eastern Gas and Fuel Associates, Boston, Mass.

in iron making, and in 1620 a patent was given Sir William St. John "to chark or otherwise to converte into charkcole, within our said realms of England and Ireland and dmion of Wales, or anie or eyther of them, all manner of seacole, stonecole, pitcole, earthcole, turf peate, brush flagg, cannell, and all other fewell or combustable matter of what nature or qualetie soever". In 1651 Jeremy Back was granted a patent to make iron with stone-coal, pit-coal or sea-coal without charking. It may thus be inferred that *charking* or coking was quite well known and practiced in England prior to that time. The word *chark* meant to burn to a black cinder, and *to char* meant to burn wood to black cinders. In *The Natural History of Staffordshire*, written by Dr. Robert Plot, "Professor of Chymistry in the University of Oxford", and published in 1686, it is recorded that coal was *charred* in exactly the same way as wood, the treated coal being then known as *coaks*. Being capable of producing just as great a heat as charcoal, it could be substituted for most purposes, but not, says Plot, "for melting, fineing, and refining of iron, which it cannot be brought to doe though attempted by the most skillfull and curious artists". Obviously, however, a *most skillfull and curious artist* by the name of Thomas Chetle of Berrow Hill in Worcestershire still lived in hope, for on December 20, 1695, he obtained a patent for smelting iron "with pitt coales or sea-coales charked".

Despite the ancient origins of coke and a fairly widespread familiarity with its preparation and properties over the centuries, the birth of the modern coking industry undoubtedly took place in England in the early years of the eighteenth century. Its founder was Abraham Darby, (1678-1717) who, for the first time, successfully used coke for the smelting of iron at Coalbrookdale in Shropshire. Abraham Darby was the son of a locksmith and farmer of the Wrens Nest, Dudley, Worcestershire, and spent his youth in apprenticeship to a malt-mill maker in nearby Birmingham. On the completion of his apprenticeship in 1699, Darby went to Bristol and there set up his own business for the making of malt-mills. There can be little doubt that his connections with the malt industry gave Darby considerable familiarity with the use of coke. The center of the malt making area at that time was the town of Derby, where coke making was first practiced on any scale and where appreciable quantities were used for the drying of malt. The making of coke in England was not, of course, restricted to the Derby district or indeed to malt making. It was beginning to be used in copper smelting, for example, where a charge of two-thirds coke and one-third coal was employed. And while referred to as *coaks* in Staffordshire, it was known as *cinders* in Scotland and Newcastle, *cowks* in Derby, *couk* in Lincolnshire, and *pitt-coale charr'd* in South Wales.

When Abraham Darby went to Coalbrookdale in 1708, therefore, coke no new or novel material. Indeed it would seem probable that its use was known in the Coalbrookdale area itself. The making of clay pipes had been carried out for a hundred years or more at Brosely, where a *cynder* fire was used for drying the pipes. It seems probable that Darby used exactly the same methods for making coke as were practiced by the maltsters at Derby, who in turn had adopted the techniques by which charcoal had been made for centuries. In charcoal burning, large circular mounds of carefully arranged logs were prepared, some sort of flue being left at the center. The spaces between the larger logs were filled with smaller pieces of wood, and the whole pile covered with turf, dirt, wet straw and leaves, etc. After burning-wood or charcoal had been pushed down the central shaft, the latter was sealed off and other vent holes made nearer the circumference. With careful control, smoldering could be made to travel outward from the middle of the heap and thus convert the whole mass of wood into charcoal. The *charking of cole* was carried out in an identical fashion. Piles of coal was built up in mounds similar to the *meilers* of the charcoal burners. In one of the first known descriptions of the procedure at Derby in 1693 it is stated that, "the collier sets six or eight waggon loads of coal in a

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Extract from *The Natural History Of Staffordshire*, by Dr. Robert Plot, 1686.

128 *The Natural Hiſtory* Chap. III.

coal yearly, others three, four, or five thouſand Tuns, the upper or topmoſt beds above the *Iron-ſtone*, lying ſometimes ten, eleven, or twelve yards thick: nay I was told by Mr. *Perſehouſe* of nether *Gournall*, that in his grounds at *Etingſall* in the pariſh of *Sedgley*, in a place call'd *Moorefields*, the bed of coal lyes 14 yards thick; in ſo much that ſome acres of ground have been ſold hereabout for a 100 pound per acre; I was inform'd of one acre, ſold for 150 pound, and well indeed it might be ſo, ſince out of one ſingle ſhaft there have ſometimes been drawn 500 pounds worth of *coal*. Nor indeed could the *Country* well ſubſiſt without ſuch vaſt ſupplies, the wood being moſt of it ſpent upon the *Iron-works*, for it is here (as well as other *Countries* that fetch their winter ſtores from hence) thought not only fit for the *Kitchin*, but all other offices, even to the *parlour* and *bedchamber*.

35. And not only in privat *Families*, but now too in moſt, if not all the *Mechanic profeſſions* (except the *Iron-works*) that require the greateſt expence of fewell; witneſs the *glaſs-houſes*, and *Salt-works*, *brick-making*, and *maulting*; all which were heretofore performed with wood or charcoal, eſpecially the laſt, which one would think ſhould hardly admit of the unpleaſant fumes of ſuch fireing: nor indeed does it, no more than of wood; for they have a way of *Charring* it (if I may ſo ſpeak without a *ſolecifme*) in all particulars the ſame as they doe wood, whence the coal is freed from theſe noxious ſteams, that would otherwiſe give the *mault* an ill odour. The *coal* thus prepared they call *Coaks*, which conceives as ſtrong a heat almoſt as *charcoal* it ſelf, and is as fit for moſt other uſes, but for *melting*, *fineing*, and *refining* of *Iron*, which it cannot be brought to doe, though attempted by the moſt ſkillfull and curious *Artiſts*. In the *glaſs-houſes*, *Salt-works*, and *Brick-clamps*, they uſe the raw *coal* as brought from the pit; in the former whereof, as to the proportion, I am not ſo certain; but in the *Staffordſhire Salt-works*, they ſpend two Tuns to a drawing; and for burning a *Clamp* of 16000 bricks, they uſe about 7 Tunns of coal. The laſt effort that was made in this *Country* for making *Iron* with *pit-coal*, was alſo with raw *coal*, by one Mr. *Blewſtone* a high-*German* who built his furnace at *Wedneſbury*, ſo ingeniouſly contrived (that only the *flame* of the *coal* ſhould come to the *Oare*, with ſeverall other conveniencies) that many were of opinion He would ſucceed in it. But experience that great baffler of ſpeculation ſhewed it would not be: the ſulphureous vitriolic ſteams that iſſue from the *Pyrites*, which frequently, if not always, accompanies *pit-coal*, aſcending with the flame, & poyſoning the *Ore*, ſufficiently to make it render much worſe *Iron*, than that made with *char-coal*, though not perhaps ſo much worſe, as the body of *coal* it ſelf would poſſibly doe.

36. In

round heap upon the ends, and as pyramidal (large at the bottom and small at the top) as they will stand". Originally, large sized lumps of coal were used in an attempt to construct a primitive flue system in the pile. Later, kindling wood was built into the heap to support the flues. Still later, vertical wooden posts were utilized. On removal of the posts from the newly built heap, holes were left into which burning coal could be dropped for ignition purposes. At about this same time wet coke breeze was being used to seal the pile instead of dirt or wet straw and leaves. By 1768, the first brick flue had appeared, for in that year John Wilkinson put up a chimney in the center of the pile. Naturally the coke yields obtained by these early pioneers of carbonization were not high. A figure of 33 pct is mentioned as being typical.

The exact year in which Abraham Darby achieved successful use of coke alone as a blast furnace fuel seems to be open to some doubt. R. A. Mott, after some of the most thorough and detailed historical research so far carried out into the subject, concluded that in 1709 Darby made more than 200 tons of coke, and that during this same year he produced the first iron to be successfully smelted by coke only. Since Darby died in May 1717, and was apparently sick for the preceding year-and-a-half, the date of his success must lie in the years 1709 to 1715.

To his daughter-in-law Darby was *a religious good man,* and this was surely virtue enough. History, however, will regard him as a great man; for truly he was the father of an industry.

From charcoal to coke in US

In America, as in England, it was the demand of a growing iron industry for blast furnace fuel which led to the establishment and development of the coking industry.

The presence of iron ore in the New World had first been discovered by members of an expedition fitted out by Sir Walter Raleigh. In 1585 the expedition landed on Roanoke Island, off the coast of what is now North Carolina. Thomas Hariot, servant of Sir Walter Raleigh, recorded that "wee founde neere the water side the ground to be rockie, which by the triall of a minerall man, was found to hold iron richly. It is found in manie places of the countrey else". Iron ore was of no interest to the expedition, however; silver and gold were what they had hoped to find.

The first iron to be made from American ore was smelted in England. The ore was taken from deposits found near to the James River in Virginia, a colony (the first permanent one in the New World) having been founded in 1607 at Jamestown by the Virginia Co. of London. Seventeen tons of metal were produced and were sold to the East India Company for £ 4 per ton.

In 1619 the Virginia Co. sent out to Virginia one hundred and fifty settlers. Included in that number were ironworkers whose task was to *set up three iron works.* Work was commenced in 1619 at Falling Creek, a tributary of the James River, some 66 mi above Jamestown, but progress was impeded by the death of three of the master artisans in charge of the project. In any event iron never was made at Falling Creek. On March 22, 1622, at which time the works must have been almost completed, hostile Indians led by Opitchapan massacred one-hundred and fifty men and women, and totally destroyed what had been so painfully and patiently accomplished.

The next attempt to manufacture iron in the colonies seems to have been made in Massachusetts. Here, in 1644, at a small village named Hammersmith, near Lynn on the western bank of the Saugus River, was established what is thought to be the first successful iron enterprise in America. It was founded by John Winthrop, Jr. and eleven other English gentlemen who formed *The Company of Undertakers for the Iron Works.* Using local bog ores, and charcoal as a fuel, about 8 tons of pig iron a week were produced.

Like many other developments, the iron industry in America gradually moved inland and westwards from the Atlantic coast. The first blast furnaces were built along the coast of Massachusetts and Rhode Island, but they were soon to spread through the states of Connecticut, New York, and New Jersey, and on into the valleys of eastern Pennsylvania. To the south, the iron industry in Virginia was revived in 1716 by the governor, Colonel Alexander Spotswood. In Maryland, a company first known as Joseph Farmer and Co. and later to become the Principio Co. blew in a blast furnace in 1724, at the mouth of Principio Creek which runs into Chesapeake Bay near the mouth of the Susquehanna River.

The fuel used in these early blast furnaces was, of course, charcoal of which abundant supplies were available from the heavily timbered country. By the end of the 18th century, however, although wood for charcoal making was still available, it was being brought to the smelting furnaces from increasing distances. The point was being reached, in fact, where it was cheaper to buy imported rather than domestic iron. In England, the scarcity and cost of charcoal a century before had forced the iron industry to search for and use a less expensive fuel, coke, and by 1796 charcoal blast furnaces in Britain were few and far between. In America a different remedy, the use of anthracite, was applied.

The use of anthracite as a blast-furnace fuel was first attempted in the latter years of the 18th century, small quantities being used to replace part of the normal charge of charcoal. Only minor percentages could be substituted in this way, otherwise furnace performance would suffer, and the iron run cold. In 1835 the Franklin Institute of Philadelphia offered a gold medal "to the person who shall manufacture in the United States the greatest quantity of iron from the ore, during the year, using no other fuel than anthracite, the quantity to be not less than twenty tons". This would seem to indicate that prior to 1835 anthracite had not been successfully used for iron ore smelting. No record exists of the award of the medal to any of the men who made it possible to produce pig iron with anthracite. Included among these was the Rev. Dr. Frederick W. Geissenhainer, a Lutheran clergyman of New York City. In a letter written to the Commissioner of Patents in November, 1837, he declared, "I can prove that, in the month of December, 1830, and in the months of January, February, and March 1831, I had already invented and made many successful experiments as well with hot air as with an atmospheric air blast to smelt iron ore with anthracite coal in my small experimenting furnace here in the city of New York". It is probable that the Reverend Doctor knew that in 1828 James B. Neilson of Scot-

land had been granted an English patent for the use of hot air in iron smelting. On December 19, 1833, a United States patent was granted to Geissenhainer for " a new and useful improvement in the manufacture of iron and steel by the application of anthracite coal". In August and September 1836 he actually succeeded in making pig iron with anthracite exclusively at the Valley furnace on Silver Creek in Schuylkill County, Pennsylvania. The real founder of the anthracite iron industry in America, however, was David Thomas, a Welshman from Glamorgan. Arriving in the United States on June 5, 1839, he started to build an anthracite blast furnace in the same year at Catasauqua for the Lehigh Crane Iron Co. The furnace was blown in on July 3, 1840, and produced good quality iron at the rate of 50 tons per week until 1879 when it was demolished. It was certainly the most successful of the early anthracite furnaces.

The fact that anthracite alone could be used as a blast furnace fuel was rapidly made use of, not only in the valleys of eastern Pennsylvania but also in New York, New Jersey, and Maryland. In 1842, twelve anthracite furnaces produced 15,000 tons of pig iron in Pennsylvania. This may be compared with the 98,350 tons which 210 charcoal furnaces in the state turned out. By April, 1846, forty-two anthracite smelting furnaces with an annual capacity of 122,720 tons were at work in Pennsylvania and New Jersey. In 1856, 393,000 tons of anthracite iron were made, and one-hundred and twenty-one furnaces in the country were either in operation or were capable of being operated; ninety-three were in Pennsylvania, fourteen in New York, six in Maryland, four in New Jersey, three in Massachusetts, and one in Connecticut. The influence of anthracite practice was also felt as far south as Birmingham, Ala., and to the west in Ohio and Wisconsin.

The effect which the introduction of the new fuel had on the iron industry, and indeed on the industrial life of the whole country, was profound. The manufacture of iron was now possible in areas where timber shortages had previously restricted it. Greater production and a measure of competition led to lower prices, which in turn served to stimulate demand. In 1864 more than 1 million tons (1,135,996 tons) of pig iron were made, 684,018 tons being produced with anthracite. Only in the year 1875 did the quantity of iron produced by coke (947,545 tons) first exceed that of anthracite iron (908,046 tons); and not until 1908 was there a really sharp reduction in the amount of anthracite iron smelted, 355,009 tons being made in that year compared with 1,371,554 during 1907. In 1921 the net tonnage of anthracite pig iron was a mere 15,392 tons, and in 1922, for the first time, no iron of that type was produced. In 1923 a slight and temporary revival occurred, 14,258 tons being made. By the end of that year, however, anthracite smelting had been abandoned.

It is rather surprising that from the time Abraham Darby established the use of coke as a successful blast furnace fuel during the years 1709-1715, more than a century was to pass until serious efforts were made to follow his example in North America. J. M. Swank, in his *History of the Manufacture of Iron in All Ages*, published in 1884, considered that the reasons for the delay were as follows: transportation facilities for bringing coke and iron ore together were lacking; of the known deposits of bituminous coal, not all were suitable for coke manufacture; the process of coke manufacture was not well understood; plentiful supplies of timber existed for the production of charcoal; charcoal pig iron was more highly regarded than any other. Cogent as these reasons may appear, they do not fully explain the late beginnings of the coking industry in America.

Early coke production in the US

One of the earliest references to the manufacture of coke in the United States is contained in a letter sent by a Mr. D. M. Randolph to Harry Heth, a mine operator in the coal fields of Richmond, Va. Randolph had been sent to England by Heth in order to look into the use of steam engines for hoisting and pumping at the mines. The letter was written from London and dated August 22, 1808. It contained the following paragraph: "I shall explain to you, how, by turning Deep Run fine coal in Coak, to make great profit from what has heretofore been useless. You will do well to ascertain the price and amount of demand for this article throughout the U. States among brewers and manufacturers. I know how also to make every bushel of such fine slaty coal, fetch as much as any of the best grate coal by turning it into Coak: and that too, after paying all expenses of the process". The knowledge gained by Randolph was evidently ahead of the times, for his suggestions were never made use of.

In the Pittsburgh *Mercury* dated April 8, 1813, there appeared an advertisement by an enterprising Englishman named John Beal who claimed the knowledge "of converting stone coal into Coak". It seems that Beal was anxious to reveal his knowledge "to proprietors of blast furnaces", no doubt on a satisfactory cash basis. His services as a consultant do not appear to have been in any great demand by the ironmasters of the day. In 1817, however, coke *made on the ground* was used by Colonel Isaac Meason in his iron works at Plumpsock, Fayette County, Pa. This was the first rolling mill west of the Allegheny Mountains to puddle iron and roll iron bars. Coke was used in the refinery. Meason's executors offered the works for sale in the summer of 1818, when the following advertisement appeared in the Pittsburgh Gazette of June 5.

"Plumpsock Iron Works, with about 350 acres of land belonging thereto. It is situated in Fayette County, nine miles east of Brownsville, and the like distance of Connellsville, five miles northwest of Uniontown. This establishment consists of a forge, rolling mill, grist and saw mills. Bar iron is made in this forge by rolling, instead of hammering, of a superior quality. Stone coal is the only fuel used in making it, an inexhaustible pit of which is within one hundred yards of the forge. Three men with a horse and cart are sufficient to raise, coke and haul to the forge all the coal necessary for keeping the works in full operation." In 1819 a blast furnace built near Lawrenceburg, Pa., was intended as a coke furnace. Owing to the weakness of the blast, among other things, it was unsuccessful and had to be taken out of operation after making 1 or 2 tons of iron. This experiment was doubtlessly one of many trials with coke which were being carried out at the time, for the records of the day indicate that considerable attention was being given to the use of coke as such, or mixed with charcoal, anthracite, and bituminous coal in the blast furnace.

The fact that successful blast furnace operation with coke had not been achieved by 1825 is evident from a letter of instruction which William Strickland received from the Acting Committee of The Pennsylvania Society for the Promotion of Internal Improvement. The letter is dated March 18, 1825. The committee were evidently much concerned by the state of the iron industry in the Commonwealth of Pennsylvania, for in their own words, "No improvements have been made in it within the last thirty years, and the use of bituminous and anthracite coal in our furnaces is absolutely and entirely unknown. Attempts, and of the most costly kind, have been made to use the coal of the western part of the state in the production of iron. Furnaces have been constructed according to the plan said to be adopted in Wales and elsewhere; persons claiming experience in the business have been employed; but all has been unsuccessful. In large sections of our state, ore in the finest quality, coal in the utmost abundance, limestone of the best kind, lie in immediate contiguity, and water power is within the shortest distance of these mines of future wealth.

"The prices which are obtained for iron on the western waters are double those of England, the demand is always greater than the supply, and thus nothing but the art of using these rich possessions is wanted.

"We desire your attention to the following inquiries on the subject of the manufacture of iron:

(1) What is the most approved and frequent process for coking coal, and what is the expense per ton or caldron?

(2) In what manner are the arrangements or buildings, if any, constructed for the coking of coal, obtaining drawings and profiles thereof?

(3) Are there different modes for coking coal; and if they have any difference in principle, what are they?

(4) In what manner are the most approved furnaces for the smelting of ore constructed? Drawings and sections of the same to accompany the information that may be obtained upon this inquiry." William Strickland journeyed to England, where he carried out his commission faithfully and intelligently. His report to the committee contained detailed plans of ovens used for coke making.

On March 4, 1834, there was read in the Senate of Pennsylvania a report containing the following statement: "The coking process is now understood, and our bituminous coal is quite as susceptible of this operation, and produces as good coke, as that of Great Britain. It is now used to a considerable extent by our iron manufacturers in Centre County and elsewhere." It is certain that the coke referred to was made on the ground and not in any type of oven. It is also extremely doubtful whether such coke was used other than as an experimental addition to the normal charcoal charge, or alternatively for melting pig iron as practiced by Colonel Isaac Meason. The fact that the Committee on Premiums and Exhibitions of the Franklin Institute in Philadelphia felt able, in 1835, to offer a gold medal to "the person who shall manufacture in the United States the greatest quantity of iron from the ore, during the year, using no other fuel than bituminous coal, or coke, the quantity to be not less than twenty tons", makes it most unlikely that coke alone had been used as a blast furnace fuel to any extent.

The rewards for successful blast furnace operation with coke were, of course, likely to be very much greater than any attractions which the Franklin Institute could offer. Nevertheless, the proposed award of a gold medal doubtless focused attention upon the problem of coke smelting, and coincidence or not, successful iron smelting with coke was achieved during the year in which the offer was made. The feat was accomplished by William Firmstone at the Mary Ann furnace in Huntingdon County, Pa. Firmstone was an Englishman who emigrated to the United States in the spring of 1835. Using coke made from Broad Top coal, he produced gray forge iron of good quality for a period of about 1 month. The coke had not been produced for smelting purposes, but was intended for use in the *run-out* fires at the forge. Whether Firmstone was aware of the Franklin Institute's offer, is not known. However, he made no attempt to claim the medal, which was, in fact, never awarded. Possibly it was the work of Firmstone that was being referred to when Isaac Fisher of Lewistown, Pa., stated in April, 1836, that "successful experiments have lately been tried in Pennsylvania in making pig iron with coke".

It was F. H. Oliphant who next produced any quantity of coke pig iron. In or about the year 1837 some 100 tons or more were made at his Fairchance furnace near Uniontown in Fayette County, Pa. Evidently difficulties in the use of coke were encountered, for after a short time it was replaced by charcoal. J. M. Swank asserts that Oliphant did know of the gold medal which had been offered by the Franklin Institute, and that he wrote of his success in a letter to the Institute dated October 3, 1837. According to Swank the letter was accompanied by a box containing specimens of pig iron, together with samples of the raw materials from which it had been produced. No trace of Oliphant's letter can be found in the archives of the Franklin Institute, but it is somewhat unlikely that such a late claim to the medal would have been considered.

Despite the success of Oliphant and of Firmstone, and despite legislation passed by the Commonwealth of Pennsylvania on June 16, 1836, "to encourage the manufacture of iron with coke or mineral coal", the use of coke for iron smelting developed slowly indeed. Many of those who did attempt it suffered disappointments and losses. For example, a Boston company spent $500,000 at Farrandsville, near Lockhaven, Pa., in an effort to establish iron and mining enterprises and to smelt the local ores by means of coke. From 1837 until about 1839 some 3500 tons of iron were made. The costs were so high, however, that further attempts to produce iron with coke were abandoned. Again, the Clearfield Coal and Iron Co. of Karthaus, Pa., produced coke iron during 1839, but in this case also operations were abandoned before the year was out, although lack of proper transportation facilities has been reported as the main reason. According to Joseph D. Weeks (*Report on the Manufacture of Coke*, Volume X of the Tenth Decennial Census: 1880), successful use of coke in the blast furnace for any considerable period was first achieved in Maryland. In 1837 the George's Creek Coal Company built the Lonaconing furnace, 8 mi northwest of Frostburg. By June, 1839, this furnace was apparently producing about 70 tons of iron per week using coke made in open pits.

Even by the year 1849 there was not a solitary blast furnace running on coke in the whole of Penn-

sylvania. There were, to be sure, four furnaces owned by the Brady's Bend Iron Co. which were classed as coke furnaces, but they did not produce iron in 1849. In his book *The Manufacture of Iron*, published in Philadelphia in 1850, Frederick Overman was able to write, "But few blast furnaces work coke in this country, and even these, as far as we know, are not in operation at the present time". Also, "as there is but little prospect of an addition to the number of coke furnaces which now exist, we shall devote but a limited space to this subject". Overman's prediction was wrong. By 1856 there were twenty-one furnaces in Pennsylvania and three in Maryland that were either using coke or were capable of so doing. In the Census Year of 1850, four coke-making establishments were listed. By 1860 the number had increased to twenty-one, and after the middle sixties coke began to occupy an increasingly important position as a blast furnace fuel.

Early coking processes in the US

The coke used in the earliest American blast furnaces to utilize it was undoubtedly produced by coking piles of coal. The quality is reported to have been excellent, although uniformity of the product was not good. Naturally the yield was low. This description of coking in piles or mounds appeared in Report L of the Second Geological Survey of Pennsylvania, published in 1876.

"The coke yard is prepared by leveling a piece of ground and surfacing it with coal dust. The coal to be coked is then arranged in heaps or pits, with longitudinal, transverse and vertical flues; sufficient wood being distributed in these to ignite the whole mass.

"Beginning on a base of 14 feet wide, the coal is spread to a depth of 18 inches, A. On this base the flues are arranged and constructed as shown in the plan—the coal being piled up, as shown in section B. The flues are made of refuse coke and lump coal, and are covered with billets of wood. When the heap is ready for coking, fire is applied at the base of the vertical flues C, igniting the kindling wood at each alternate flue.

"As the process advances, the fire extends in every direction, until the whole mass is ablaze. Considerable attention is required in managing this mode of coking, in diffusing the fire evenly through the mass, in preventing the waste of coke by too much air at any place, and in banking up the heaps with fine dust as the operation progresses from base to top.

"When the burning of the gaseous matter has ceased, the heap is carefully closed with dust or duff, and nearly smothered out in this way. The final operation is the application of a small quantity of water, down the vertical flues, which is quickly converted into steam, permeating the whole mass. This gives coke with the least percentage of moisture, if carefully applied.

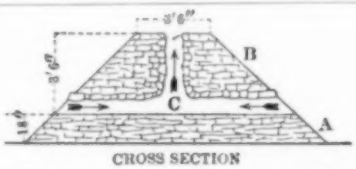
"The time necessary for coking a heap, with the Bennington coal, is from 5 to 8 days—depending mainly on the state of the weather."

A coke yield of 59.1 pct is given for mound coking as carried out at the Bennington yard, and this tallies well with a recovery of 59.6 pct quoted for the process at Holidaysburg. However, A. W. Belden (Technical Paper No. 50, issued by the Bureau of Mines in 1913) commented that yields of almost 60 pct could only have been achieved by taking special pains to produce the highest possible quantity of good coke, and that 50 to 55 pct would have been more representative of the average mound coke producer.

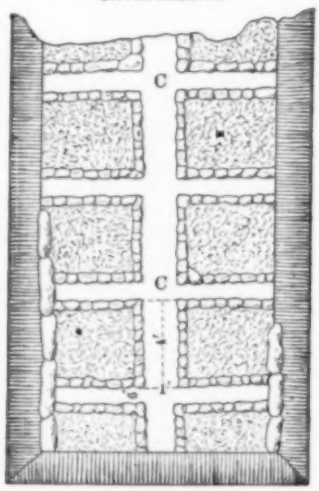
Frederick Overman, to whom reference has already been made, was a great champion of coke made in the open air, and saw little virtue in that which was produced in ovens. The following passages have been taken directly from his book, *The Manufacture of Iron, In All Its Various Branches*, (1850).

"The manufacture of coke for blast furnace purposes is generally carried out in the open air, either in round heaps or rows; the latter mode is generally preferred. Coke burned in ovens will answer for that which is used in the furnace of locomotives, or for the purpose of generating steam; it is even useful in a foundry cupola oven; but in the blast furnace, or even in the refining fire, it ought not to be applied, for reasons we shall presently explain.

"Cases may occur where coking in ovens may be permitted even for blast furnace coke; as for instance, where a very brittle coal, but free of sulphur, is to be charred. But these cases are rare, at least in the coal fields at present worked; for all our coal, when compared to the coal which is employed in the blast furnaces in Europe, may be considered more or less sulphurous. However that may be, coke ovens are practicable; at least, they are at present in general use in the Pittsburgh coal fields. All the coke used in cupola ovens and refining fires in the Western states is made in ovens. Coke ovens of various forms have been erected, sometimes with regard to quality, but most generally to quantity; and for the latter purpose they have been brought to great perfection. In our case, quantity is of secondary consideration; the obtaining of coke, free of bitumen



CROSS SECTION



GROUND PLAN

Coke mound or pile.

and sulphur, is the object at which we aim. All the various coke ovens are constructed mainly upon one principle; that is, they are built in the form of a common bake oven, and generally of capacity sufficient to receive a charge of two or three tons of coal at once. Some are round; others egg-shaped; and at the Clyde Iron Works, in Scotland, the hearth is square. *Ure's Dictionary of Arts and Manufactures* contains a description of an excellent arrangement for coking coal, erected for the use of the locomotive engines of the London and Birmingham Railway Company, but we doubt the utility of such ovens in iron establishments for we cannot believe that the large quantity of coke yielded is of quality sufficiently good for the manufacture of iron. In Germany and France, coke ovens have been built of admirable construction, as far as the saving of fuel is concerned, but iron masters who require a good article burn coke in the open air.

"As we have previously remarked, there is but little prospect of seeing coke furnaces in successful operation in the United States. Nearly every state in the Union has good raw coal in sufficient quantity, as well as of proper quality to supply its furnaces."

Overman's *preferred* method of coking in rows or long heaps is described thus: "These rows are sometimes one-hundred feet long, seven or eight feet wide, and three feet high. To coke in rows, a yard is to be levelled sufficiently large to hold as much coal as is required to keep the furnaces in operation. Along, or all around, this yard, it is advisable to have a ditch dug, which will hold a regular supply of water throughout the year; this water ought not to fail during the driest seasons. A row is started at that end of the yard most convenient for the transportation of the raw coal, and directed in a straight line towards a point on the opposite side of the yard. Should there be a deep covering of coke dust all over the yard, a kind of ditch, as broad as the coal pile is designed to be, may be prepared by scraping the dust from the middle, and drawing it towards the spaces between the rows. This ditch will indicate the direction in which the coal is to be laid, and will bring it close to the moist ground. The scraped coke dust is afterwards used for covering the heap. The coal is arranged as in the above case (authors' note: coarse coal at the bottom and in the center). Due attention should be paid to placing air-channels, or draft holes, at the bottom, and to throwing the coarse coal in the centre. At a distance of seven or eight feet from each other, tapered posts seven or eight inches in diameter, are fastened in the ground, around which the coarsest coal is arranged. These posts or poles are removed before the heap is fired, and are designed to form chimneys, for the free vent of gaseous matter, and the increase of draft. When the pile extends twenty feet or more, and it is covered with small coal, slag, or coke dust, fire may be put to the heap at different places near the air holes; and the row may then be continued. In this way it will happen that coke is drawn at one end of a row, and coal is set at another. After fire is kindled, and the heat extended to the center, the pile may be covered more closely, with due attention to leaving some air-holes near the top; and in case these holes are shut by the expansion of the coal, they should be re-opened by means of iron bars run down to the center of the pile, or at least to the fire. When the white flames of carburetted hydrogen cease to be visible, the heap and air-holes may be closely covered by coke dust, and the coke left to cool. This method of making coke for the blast furnace has, thus far, been preferred to any other method. For this preference the following reasons may be assigned: the small body of coal in fire at one time; the large surface of ground it covers, thus presenting unequalled facilities for the circulation of watery vapors through the hot coke; and the chance it affords of retaining the heat till the advantages of steam are produced. For these reasons a water ditch around a coke yard is required to keep the ground moist; besides, water is frequently needed to choke the fire where it continues too long in the heap, and thus to drive the steam through the hot coke. For the same reason, a yard does not make good coke if it is covered too thickly with coke dust."

Overman's theory of carbonization placed great emphasis on the benefits to be derived from "the circulation of watery vapors through the hot coke". "Good coke", he writes, "ought to be silvery white and compact; it ought to sound like good crockery ware and should be free of bitumen, hydrogen, and sulphur." Water quenching he was not at all in favor of. "In some establishments, workmen have been advised to sprinkle water over the red-hot coke, which may be done from the nose of a watering-pot, partly with the object of expelling the remaining sulphur, and partly with the object of extinguishing the fire. This is a bad habit; it inures the coke, makes it rotten, and seriously impairs its utility in the blast furnace." To the reader of today, Mr. Overman's views upon coke and coking sound quaint indeed. Perhaps we should not judge him too harshly, however, and even the most critical tends to find himself mollified by a preface which disarmingly states that, "This work contains imperfections for which we cannot consistently ask the indulgence of the reader. It may even embody errors; these, on the ground of human frailty, may be deemed, by the kind-hearted reader, excusable."

Open-air coking was, of course, wasteful and lacking in control, and the next step in the development of carbonization practice was no doubt the use of rectangular brick enclosures which were left open at the top. The side walls of these precursors to the oven were between 5 and 8 ft tall and contained holes provided for the entry of air. The method of coking was identical to that followed when coking in mounds. From this it was a logical development to provide the walls with a roof to make a fully enclosed oven. The original shape may have been suggested either by the dome-shaped mound used for coking or by the form of the charcoal kiln.

(To be continued)

Development of the Coke Industry During the 19th Century

Year	Number of Establishments	Year	Number of Establishments
1850	4	1889	252
1860	21	1890	253
1870	25	1891	243
1880	149	1892	261
1881	197	1893	258
1882	215	1894	260
1883	231	1895	265
1884	250	1896	341
1885	233	1897	336
1886	222	1898	341
1887	270	1899	343
1888	261	1900	388

ANALYSIS OF OPEN HEARTH OXYGEN INJECTION

Results are presented of a program designed to investigate the effects of using oxygen for the enrichment of the combustion air, and to determine the effects of oxygen flow rate and velocity through roof lances.

by J. E. Howkins, R. J. Fekete, G. A. Ferris, and W. R. Kiessel

The use of oxygen in steelmaking operations is becoming increasingly important. In recent years, the advent of the LD process, the Kaldo process, and the Rotor process have opened up new possibilities for more economical production of steel. Open hearth furnaces with capacities of 200-tons are being supplanted by 30-ton oxygen vessels which produce steel at approximately three times the rate of the open hearth. On the other hand, a large sum of money is invested in the open hearth throughout the country, and there is a lot of work being undertaken to increase the rate of production in the open hearth. Oxygen is being used extensively for this and consequently for reducing the costs of producing steel.

These pertinent factors made it necessary to investigate the effects of using oxygen in Ford's open hearths. A representative furnace was chosen for the test, and a program was designed to investigate the effect of using oxygen for enrichment of the combustion air and to determine the effects of oxygen flow rate and velocity through roof lances. The oxygen for enrichment was fixed at one flow rate because of mechanical limitations. Two flow rates and two types of lances are used for the refining period. In addition, the hot metal level was varied to study the effect of the percentage of hot metal on heat time.

Experimental practice

The furnace on which the tests were carried out was a 215-ton furnace with single-pass checkers. Preliminary tests with oxygen with a silica roof were limited by damage to the roof caused by the higher temperatures. A basic roof was installed for the tests described in this paper.

Two lances were suspended in the middle of the furnace behind the second and the fourth of five doors. The lances could be adjusted to any desired height and when in operation, they were maintained at a height of about 6 in. above the bath. Immersion of the lances in the slag was not tried initially because of lack of experience, but it was found later that the lances could be immersed in the slag at high oxygen flow rates.

Two types of lances were used, differing in the number of oxygen outlet holes in the tip. Type A lance had four holes, each ½-in. in diam, arranged to jet the oxygen out symmetrically around the lance at about 20 degrees to the vertical. Type B lance had the same tip design, except that six ½-in. holes were used instead of four.

Two oxygen flow rates were used for the main part of the test, 20,000 standard cu ft per hr (cfh) and 30,000 standard cfh, giving calculated velocities of 1020 ft per sec (fps) and 1530 fps for the four hole lance and 680 fps and 1020 fps for the six hole lance. These velocities are the conventional way of expressing flow rate per lance orifice and are calculated from the flow rate of the oxygen under standard conditions divided by the number of holes in the lance head and the area of each hole. Higher flow rates have been used, and it has been found that the increased foaminess of the slag prevents excessive splash. The lances were lowered immediately after the finish of hot metal.

The end burners in the furnace are designed to burn both gas and oil. Oxygen was used on some heats through the gas section of the burners to decrease the meltdown period. With oxygen enrichment, it was possible to increase the fuel rate by 20 pct to get the same flame length as before.

The furnace charges used during the tests were maintained at a constant total metallic charge of 490,000 lb. Non-oxygen heats were operated on a 58-pct hot-metal basis; however, since the quantity of ore was reduced in oxygen heats, the hot metal was adjusted to keep the total metallics constant. In

J. E. HOWKINS, R. J. FEKETE, G. A. FERRIS, and W. R. KIESSEL are with the Ford Motor Co., Dearborn, Mich.

one series of tests, 60-pct hot metal was charged, and in a series of oxygen heats, designed to show the effect of a smaller percentage of hot metal, a 51-pct hot metal charge was used. Heats with delays, which were outside of the control of the operator, were not used in the analysis of the results. Similarly, heats which had additions of hot metal or pig at the end of the heat were not included. All heats used for this test analysis were low carbon—approx 0.06 pct. The accepted test heats were easy to analyze as a result of the consistent practice, but an allowance for delays, based on experience, must be made when the test results are applied to regular operation.

Normal sampling procedure was followed. A metal sample taken early in the refining period was analyzed for phosphorus, sulfur, manganese, and residual elements. Metal and slag samples taken towards the end of the heat were analyzed for sulfur, manganese, and iron oxide. Metal samples for carbon were taken throughout most of the refining period and analyzed in a magnetic type carbon analyzer. The composition of the hot metal was determined at the blast furnace. In addition to these analyses, additional samples were taken at regular intervals throughout selected heats for complete metal and slag analyses. The results of these were used for material and heat balances. Vacuum pin samples were taken from behind No. 2 and 3 doors at the same time as the metal and slag samples, and these pin samples were tested for oxygen content of the metal.

Bath temperatures were taken periodically throughout the heat by immersion thermocouples, and the temperature of the hot metal charged was taken by optical pyrometer.

Averages of the results were obtained, and their accuracy was determined by statistical methods for establishing the 90-pct confidence limits. All times were calculated from the time of start of charge. Carbon results from the carbon analyzer were recorded, but only results below about 1.3 pct C could be used, owing to the inaccuracy of the carbon analyzer above this carbon content and to the bath being incompletely melted. When carbon-time plots were made for the individual heats, it was evident that the lines for heats with oxygen were approximately straight, and that the slopes of the lines for heats with the same oxygen practice were almost identical. Two methods were used to compute the average rate of carbon drop for any oxygen practice. The first method consisted of moving the individual curves so that they crossed at the point of 0.50 pct C. A regression line was computed by the method of least squares, and the average rate of carbon drop was determined. An indication of how well the regression line fits the points is given by the correlation coefficient. A straight line was not very accurate for the non-oxygen heats because of the change in slope at low carbons. The second method for determining the average rate of carbon drop was to calculate the slope of the regression line for each heat and then determine the average value for the heats with one oxygen practice. This method had an advantage in that it lent itself to an analysis of variance of the slopes to determine if the average rate of carbon drop was different in one practice from another practice. Again, the results were determined at the 90 pct significance level.

Results

The variations in oxygen usage through the burner and the two types of lances, and the average results for each group of heats are shown in Table I. The observations were taken through two furnace campaigns, excluding the first and last few heats so that the condition of the furnace was not a major factor.

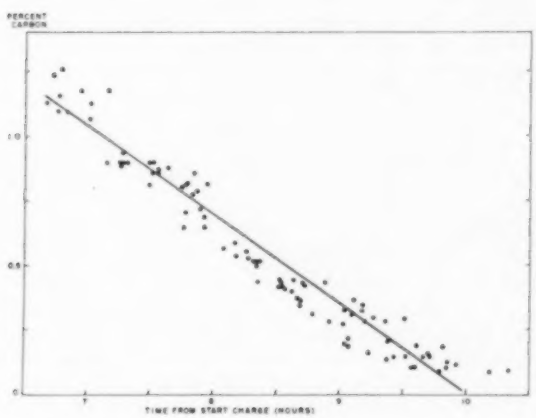


Fig. 1—Above, Carbon points and regression line for non-oxygen heats.

Fig. 2—Right, Carbon points and regression line for Type A lance heats at 20,000 cfh oxygen.

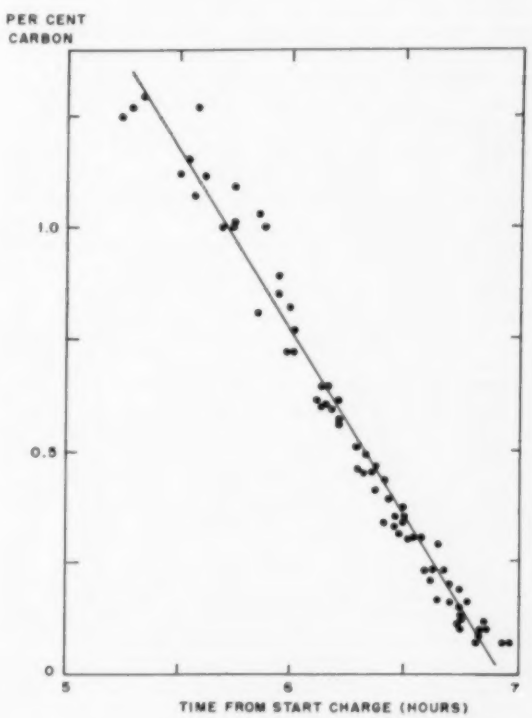


Table I. Summary of Results

Schedule	Charge to Tap, hr	Yield[a]	Prod. tph	Fuel		FeO, pct	S Ladle, pct	Burner O_2, cu ft/ton	Lance O_2, cu ft/ton	Carbon Drop, pts/min[b]
				SC to Tap, gals	MM BTU/ton					
Non-oxygen heats	10.50	86.37	20.73	5884	4.02	16.3	0.030	—	—	0.57
Type A lances 0/20,000 (Burner/lance O_2)	7.16	85.08	29.54	3132	2.20	21.31	0.024	—	676	1.38
Type A lances 0/30,000	6.86	81.49	29.85		2.26	25.40	0.022	—	939	1.77
Type B lances 0/20,000	7.38	82.87	28.37		2.10	25.04	0.022	—	711	1.30
Type B lances 0/30,000	6.68	82.09	29.89		2.09	23.27	0.021	—	978	1.54
Type A lances 0/20,000 (51 pct hot metal)	7.62	84.11	26.75		2.94	20.65	0.025	—	645	1.42
Type A lances 25/30,000	5.58	83.18	37.07	2465	1.77	21.42	0.025	223	832	1.84
Type A lances 25/20,000	6.43	85.04	33.02		2.09	20.77	0.024	282	648	1.53
One Type A lance 25/20,000	8.00	82.57	26.17		2.83	20.15	0.026	281	460	0.99

[a] Yield based on metal charged, metallic content of additions, and usable ingot tons.
[b] The carbon points for each heat were adjusted to make the carbon-time curves for all heats pass through a common point at 0.5 pct C. This rate of carbon drop is the value of the gradient of the regression line through all the points.

There was no noticeable effect of oxygen on the fettling time following the heats.

Yield

To get an accurate yield figure, the 16 non-oxygen heats were combined with 10 other non-oxygen heats made under approximately the same conditions during a period not covered by the test. All the oxygen heats were combined except for those with low hot metal percentage to give 100 heats. The average yield (usable ingot weight divided by metallic charge + furnace additions + ladle additions) for the non-oxygen heats was 87.3 pct, made up of 86.4 pct for the 16 tests heats and 88.7 pct for the 10 non-test heats. This figure of 87.3 pct is in good agreement with the average yield for the shop with essentially a non-oxygen practice. When the weight of sculls and butts was added to the usable ingot weight, the yield became 88.1 pct. The average yield, including sculls and butts, for the oxygen heats shown in Table I was 84.2 pct. If we take into account the larger quantity of metalloids, due to the higher percentage of hot metal in the oxygen heats, the average difference in yield becomes 3.7 pct. Applying a statistical test, we can say with 90 pct confidence that the difference in yield between oxygen and non-oxygen heats was at least 2.7 pct. This difference may be attributable to several factors. Fumes and splashing may account for up to 1.5 pct [1,2]. According to simple correlations of results from these tests, the 6 pct increase in FeO in the tap slag found in the oxygen heats accounts for a 0.6 pct loss in yield. In addition, there is an effect from the use of predominantly different mold sizes in the oxygen and non-oxygen heats. Owing to errors in the weights of ingots from certain molds, another yield loss of approximately 0.5 pct may be accounted for. These account for the explained yield loss of 2.6 pct. It should be noted that these yield figures were obtained only from heats in which 20,000 and 30,000 cubic feet/hour of oxygen/lance were used since only a few yield figures have been obtained for heats with the higher oxygen flow rates.

Sulfur

The average sulfur content in the ladle for the non-oxygen heats was 0.030 pct. The average ladle sulfur in the oxygen heats was 0.024 pct. The average difference of 0.006 pct was shown by statistics to be highly significant. There was no significant difference between the ladle sulfurs in the heats using oxygen for air enrichment during meltdown and the other oxygen heats.

Ladle sulfur differences in the oxygen and non-oxygen heats have been attributed [3] to the slag being hotter and more fluid earlier in the heat with oxygen usage. There is also a greater agitation in the bath which increases the rate of transfer of sulfur to the slag. A higher oxidation potential in the metal and slag may also assist in achieving lower sulfur contents in the oxygen heats[4].

Iron oxide

A comparison of percentage FeO in the slag as reported in the slag analysis taken near the end of the heat showed an average of 16.0 pct for the non-oxygen heats and 22.1 pct for the oxygen heats, giving an increase of 6.1 pct FeO in the slag due to the use of oxygen. This means that some of the lance oxygen is being used to oxidize the slag instead of the carbon [5]. There was no significant difference at the 90 pct level between the FeO contents for the heats using the four hole lances and those with six hole lances, or between the heats with 20,000 cfh and those with 30,000 cfh.

Carbon drop

Carbon points and regression lines for the first three groups of heats in Table I are shown in Figs. 1 through 3. Two oxygen practices were compared by doing an analysis of variance on the carbon drop rates of the two sets of heats. Taking a significance level of 90 pct, we can state the results as follows:

1) With the four hole lances there is a significant difference between the average rate of carbon drop of 1.38 points per min with 20,000 cfh oxygen and 1.77 points per min with 30,000 cfh;

2) With the six hole lances there is a significant difference between the average rate of carbon drop of 1.30 points per min with 20,000 cfh oxygen and 1.54 points per min with 30,000 cfh;

3) Using 20,000 cfh oxygen, there is no significant difference between 1.38 points per min for the four hole lances and 1.30 points per min for the six hole lances;

4) Using 30,000 cfh oxygen, there is a significant difference between 1.77 points per min for the four hole lances and 1.54 points per min for the six hole lances; and

5) There is no significant difference between the carbon drop rate of 1.38 points per min for the oxy-

gen heats with high hot metal and 1.42 points per min for those with low hot metal.

A comparison of the rates of carbon drop with each of the two types of lances at the two oxygen flow rates shows that an increase in oxygen flow from 20,000 to 30,000 cfh increased the rate of carbon drop by 18 pct for the six hole lances and by 28 pct for the four hole lances. This apparent discrepancy between the 50 pct increase in oxygen and the lower percentage increase in the rate of carbon drop may be explained in the following way: The oxygen which reacts with the carbon comes from three main sources: lance oxygen, ore, and the furnace atmosphere by diffusion through the slag. If it is assumed that the amount of oxygen from the atmosphere and the ore would cause the same rate of oxidation of the carbon as in the non-oxygen heats, the rate of carbon drop in the regular heats (0.57 points per min) can be subtracted from that in the oxygen heats to determine the rate of carbon drop due to the lance oxygen alone.

There is more splashing of the metal at the higher oxygen flow rates and velocities. An increased amount of splashing will produce a greater surface area, resulting in a higher rate of carbon oxidation from the furnace atmosphere. Hence, the value of 0.57 points per min, may not be the same for all the variations in oxygen usage, but it may be considered to be a reasonable approximation to get a measure of the effectiveness of the lance oxygen alone. Another factor not taken into account is the difference in the amount of charge ore in the oxygen and non-oxygen heats, but the effect of the charge ore on the rate of carbon drop is negligible in the carbon range below 1.2 pct.

Another important factor determining the rate of carbon drop is the velocity of oxygen from the lance. A comparison of the four and six hole lances at the two oxygen flow rates gives a ratio of 1.11 in the carbon drop rates for the two lances at 20,000 cfh and a ratio of 1.24 at 30,000 cfh. It has been shown that the 11 pct increase in the rate of carbon drop is not significant. The 24 pct increase is significant and shows that, on the average, the four hole lance is 24 pct more effective than the six hole lance at 30,000 cfh oxygen. If area alone is taken into account, the four hole lance should give a velocity one and a half times that from the six hole lance. However, this figure of 1.5 is only true for oxygen at atmospheric pressure and 60°F with no pressure drop in the lances. Pressure drop is greater at higher velocities and increases rapidly as the velocity of sound (1030 fps in oxygen at 14.7 psia and 60°F) is approached. As the pressure drop increases, the pressure of oxygen inside the lance increases, causing the density of the gas to become higher and the exit velocity lower. The higher velocities, calculated on the basis of flow divided by area, are, therefore, less realistic than the lower ones. It follows that the velocity from the four hole lance was less than 1.5 times that from the six hole lance. The increase in rate of carbon drop at an increased velocity is due to the increased splashing from the bath and the increased turbulence in the bath. The eddy diffusivity, as the measure of turbulence, and molecular diffusivity are additive. The sum of the two governs the rate at which the oxygen is transferred from underneath the lances to all parts of the bath.

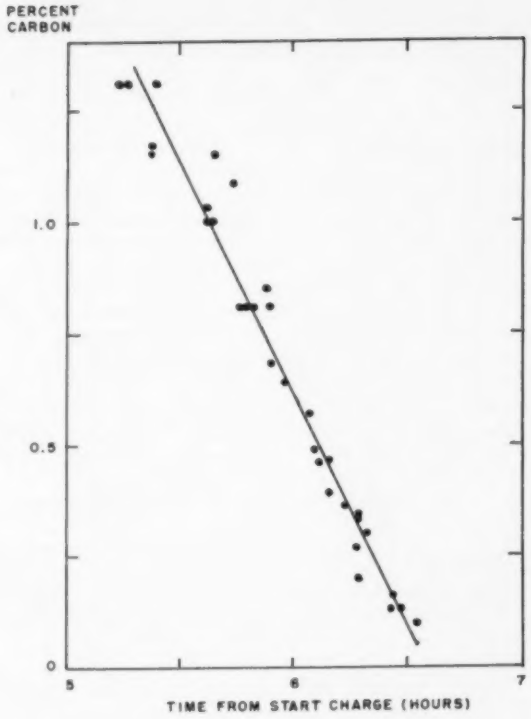
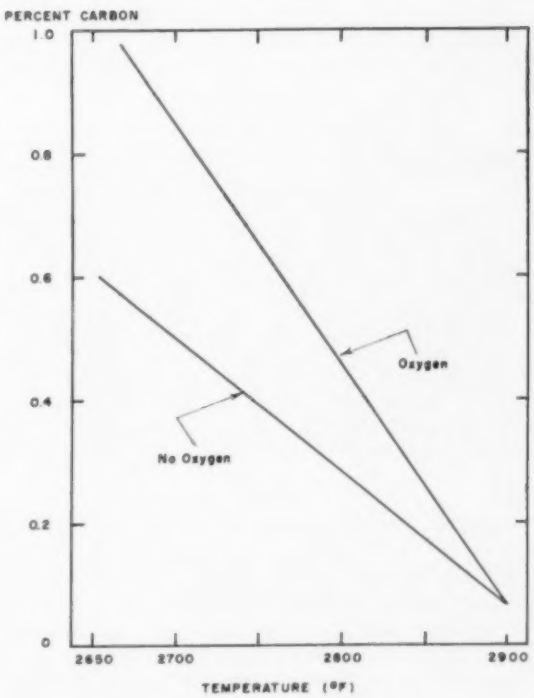


Fig. 3—Above, Carbon points and regression line for Type A lance heats at 30,000 cfh oxygen. Fig. 4—Below, Carbon-temperature relationships for oxygen and non-oxygen heats.



The rates of carbon drop were also a means of establishing the similarity of the furnace conditions during the two furnace campaigns.

Heat times

Heat time may be reduced by at least 1.16 hr by the use of 25,000 cfh oxygen through the burners. For purposes of comparison between heats with and without burner oxygen, the hot metal should be added to the furnace when the same amount of heat has been absorbed by the scrap. In practice, however, it was difficult for the operators to become accustomed to the shorter meltdown periods using burner oxygen. At the beginning of the test, the reduction in heat time using burner oxygen was only 0.76 hr, but, as more experience was gained, the average time saved was 1.16 hr. The meltdown period (start charge to finish hot metal) was reduced to an average time of 2.7 hr with a minimum of 1.9 hr. With higher oxygen and fuel input rates the meltdown period may be decreased even further to the point where material handling becomes the main limitation. If the rate of charge of scrap and hot metal can be speeded up, the meltdown period may be reduced even further. The smaller amount of heat absorbed during the charging period must be balanced against a larger heat input during refining; this results from a greater rate of oxygen usage.

Oxygen through one lance at 20,000 cfh reduces the heat time by an average of 1.74 hr, whereas, the addition of another lance with the same oxygen flow rate through it only reduces the heat time by an additional 1.57 hr.

An increase from 51 to 60 pct hot metal causes a shorter heat time by 0.59 hr when the same oxygen conditions are maintained in both groups of heats.

The significant difference between the rates of carbon drop for the four and six hole lances at 30,000 cfh does not show in the difference of heat times. There is only a difference of 0.02 hr, and there is a high variance of 0.51 for the four hole lances at 30,000. The lack of significance is caused by the large variation of heat times and the small number of heats.

Pct hot metal

The decrease in production using the 51 pct hot metal charge can be accounted for by the increased charging time for the higher percentage of scrap. The extra drag of cars required increased the charging time by approximately 50 pct, and there was no substantial decrease in the hot metal addition time. The time from finish hot-metal charge to tap was about the same as for the 60 pct hot metal charge and the same oxygen practice. Hence, it may be concluded from these results that a change from 60 to 50 pct hot metal, per se, does not affect the heat time, but that the heat time is longer by an amount equal to the time to charge the extra scrap.

Fuel

The fuel rate of 4.02 million Btu (charge-to-tap) per ton in Table I for the non-oxygen heats is high compared with the shop average for nine 200-ton furnaces of 3.55 million Btu (tap-to-tap) per ton for the year 1959. It is possible that the difference is caused by the checkers being choked by the additional flue dust from the oxygen heats. The decreased fuel usage, down to 1.77 MM Btu (tap-to-tap), in the oxygen heats is caused by the shortened heat time, increased rate of heat evolution from the exothermic oxidation reactions and less ore needed.

Temperature

Temperatures were taken throughout most of the refining period and these were used to give temperature-carbon curves for oxygen and non-oxygen practice. Heats with lance oxygen flow rates of 20,000 and 30,000 cfh were used to get the curve for oxygen practice. These curves are shown in Fig. 4. To obtain these curves it was necessary to use the heats which had hot metal or pig added at the end so that an estimate could be made of the optimum temperature for each percentage carbon. If the heat ends soft, i.e. with the necessary amount of carbon but with too low a temperature for tapping, hot metal or pig must be added; this is indicative of too much oreing. The curves may be used to find out what the temperature should be, if the heat is to finish with both carbon and temperature ready to tap. If the temperature is to the left of the appropriate curve for the oxygen or non-oxygen practice at the bath carbon percentage measured, no ore should be added. If the temperature is to the right of the curve, ore may be added, the amount of ore depending on the distance from the curve. For example, in an oxygen heat, if the carbon sample shows 0.80 pct C and the temperature is 2700°F, it can be seen from Fig. 4 that the point lies to the left of the curve for oxygen heats; hence, no ore should be added. However, if the temperature is, say, 2730°F at the same carbon percentage, this point is slightly to the right of the curve, and about one half box or approx 3000 lb of ore may be added. If the carbon and temperature readings are taken simultaneously several times in the heat, the curves may be used to prevent delays at the end of the heat.

Oxygen samples

The pin samples taken during a few of the test heats were analyzed for oxygen by vacuum fusion.

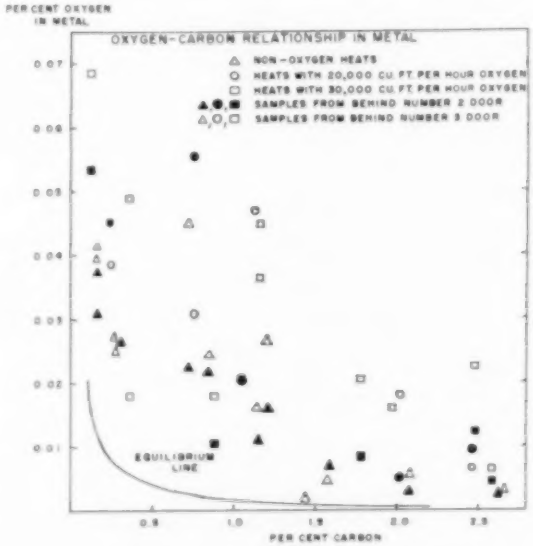


Fig. 5—Oxygen-carbon relationship in metal.

The results are plotted in Fig. 5 on a carbon-oxygen graph. The carbon-oxygen equilibrium line obtained from Fuwa and Chipman's[6] results is also plotted for comparison, the temperatures being taken from Fig. 4 at the different carbon percentages.

In general, the samples taken from the non-oxygen heats are lower in oxygen percentage than those from the oxygen heats. There is no visible difference in the oxygen contents of the samples from the heats with 20,000 cfh and those with 30,000 cfh oxygen. This means that the reaction rate with carbon is high. There is also no distinguishable difference in the samples from two and three doors, showing that the rate of diffusion of the oxygen across the bath is quite high.

High oxygen rates

The experience gained from this series of tests indicated that the meltdown time could be cut shorter and the rate of carbon drop increased by higher oxygen velocities or higher flow rates during the refining period. This led to a number of tests using fast charging techniques and oxygen rates of about 50,000 cfh through each of two lances. Oxygen was used through the end burners during the meltdown period, and the oxygen through the lances was turned on immediately after the hot metal had been added.

Results from a few preliminary tests have been combined to give an average rate of carbon drop using two type B lances. This rate of carbon drop is compared with the main results from Table I in Fig. 6. The comparison shows that it is possible to project the rate of oxygen usage to obtain the rate of carbon drop at a higher oxygen rate.

Material and heat balances

Material balances were made on three representative heats to compare heats with no oxygen and lance oxygen at 20,000 and 30,000 cfh. Manganese and phosphorus contents were used to compute the weights of the flush and tapping slags, and the results of the chemical analyses run throughout the heats were used to obtain the iron contents. The results of the material balances indicate a large amount of iron loss ranging from approx 12.7 pct for the non-oxygen heats to approx 13.5 pct for the oxygen heats. This loss includes weighing errors, hot metal losses during charging, scrap spillage during charging, steel left in the bottom of the furnace at tap, steel in the slag pot, fumes, and splash.

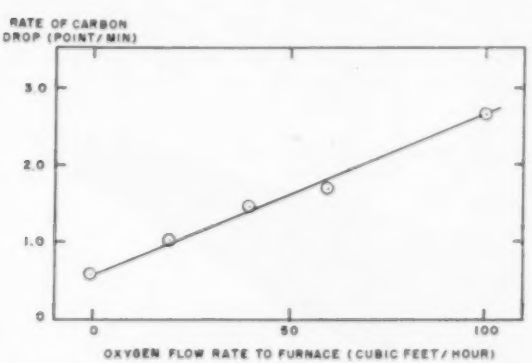


Fig. 6—Effect of oxygen flow rate (x10³) on rate of carbon drop.

Heat balances were made by using the results of the material balances. The heat in and heat out were determined, and the difference was the heat which was made up by burning fuel.

The greatest difference between the heat balances for the oxygen and non-oxygen heats is in the total heat required ranging from approx 85.0 x 10⁶ Btu for oxygen heats to approx 151.8 x 10⁶ Btu for the non-oxygen heats. The heat required is that which must be supplied by fuel. The heat in was practically the same in the three balances; the factors causing the difference in the outputs are the heat needed to decompose the ore and the heat carried off in the slag. These are both a function of the amount of oxygen or ore used. Less ore is used in the oxygen heats; hence, less heat is absorbed and, also, less silica is formed from the ore, resulting in a lower slag volume.

Summary

One of the best ways to determine with any accuracy the effect of oxygen on production is to run a series of controlled tests. It is then possible to eliminate many of the variables which occur in normal practice and separate out the effect of oxygen on heat time. In the tests described in this paper, the heats were controlled to keep as many of the conditions constant as possible. All heats were observed and samples taken throughout the refining period in a few heats. The heats were not randomized, due to operation limitations, but the results were analyzed statistically to determine variances, significance levels, and confidence limits.

Curves for oreing practice during oxygen and non-oxygen heats have been drawn to facilitate the decision on the time to add ore in the heat. The curves depend on frequent carbon samples and bath temperatures being taken.

Heat and material balances were made on three heats which were sampled throughout. The material balances show that the main yield loss in open hearth furnaces is due to a summation of several factors, including sculls, butts, weight errors, and metal left in the furnace. In the heat balances, the main difference between the oxygen and non-oxygen heats could be accounted for mainly in the difference in the amount of ore used in the two practices.

The results from the rate of carbon drop were utilized in heat and material balances to predict the feasibility of using a high rate of oxygen and short charge times. Following these preliminary calculations, a series of short heats were run using 50,000 cfh oxygen and burner oxygen with fast charging. The results are indicative of the possibility of further reductions in heat time using even greater quantities of oxygen.

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OXY-FUEL INCREASES OPEN HEARTH POTENTIAL

Experimental practice developed at Ford has indicated a potential of more than 65 tph on a 200-ton open-hearth furnace. In this article, the author describes results of heats on a 400-ton furnace which have given an output of over 100-tph.

by G. A. Ferris

Most open-hearth plants, especially those with a quantity of oxygen available, have established experimental programs or practices to develop the open-hearth process to the degree that best suits their requirements.

The Steel div. of Ford Motor Co. has tested a procedure which employs a 50-pct hot-metal charge with emphasis on the speed of cold and hot metal charging, combined with an extremely high firing rate through the hot-metal addition, and the extensive use of oxygen thereafter.

Using this practice, 25 heats have been produced on a 200-ton open-hearth furnace at an average of 67 tph, charge-to-tap with a consumption of 1,520,000 Btu and 1676 cu ft of oxygen per ton. Ten heats have also been produced on the 400-ton furnace at an average of 96 tph, charge-to-tap. The best results were 70 tph on a 200-ton furnace with a consumption of 1,368,000 Btu and 1575 cu ft of oxygen per ton, and 105 tph on the 400-ton furnace with a consumption of 723,000 Btu and 1500 cu ft of oxygen per ton.

Facilities

The open-hearth shop consists of ten furnaces: nine tapping 200-ton heats and one tapping 400 tons into two ladles. The large furnace and one of the small furnaces are equipped with basic roofs and oxygen roof lances.

The furnaces are serviced on the charging side by two 125-ton hot-metal cranes, one 15-ton stock crane, and four 12-ton charging machines. Hot metal is handled from one end of the shop, either directly from blast furnace ladles or from two 500-ton mixers. Raw material handling (scrap, limestone, and ore) is accomplished in the area adjacent to the charging floor by five 15-ton stock cranes, loading directly from railroad cars or inventory piles to charging buggy. Buggy movement between the stockhouse and charging floor is directed through four crossover tracks. The pit side is serviced by four ladle cranes with sufficient pouring platforms for handling seven heats.

The 400-ton furnace is equipped with four oxygen-fuel roof lances and conventional end burners, capable of burning oil with oxygen enrichment. The bath depth is 45 in. Bunker C oil is employed through the end burners, and natural gas, supported by oxygen, is used through the roof lances. Atomization is provided by super-heated steam at 200 psi. Natural gas and oxygen are delivered at 45 and 125 psi, respectively. The furnace is controlled automatically insofar as fuel: air ratios, reversals, and pressure control are concerned.

The oxygen-fuel lances were designed by Air Products Corp. and developed by their engineers in Ford open hearths in conjunction with operating personnel. These lances have six ½-in. openings which are 30 degrees from the vertical. A maximum of 60,000 cu ft of oxygen per hr or oxygen mixed with 30,000 cu ft of natural gas per hr may be delivered through these lances. Using maximum volumes, the mixture produces a flame temperature in excess of 4500°F.

Charging and melting

For the best heat on the 400-ton furnace, the total metallic charge was 944,000 lb, consisting of 444,000 lb of scrap and 500,000 lb of hot metal. The total charge, including 15,000 lb of burnt lime, was contained in 20 buggies. With every emphasis placed on scrap density and high uniform buggy weight, the average scrap buggy weight was 24,700 lb in three 35-cu-ft boxes per buggy. Charge lime was spread over the hearth and sandwiched between the scrap.

Maximum end firing was maintained throughout charging at the rate of 14 gal of oil per min enriched with 500 cu ft of oxygen per min. The roof lances were lowered approx 1 ft during the charging period. They used 30,000 cu ft of natural gas mixed

Typical oxy-fuel lances employed at Ford Motor Co. Courtesy Air Products Inc.

G. A. FERRIS is operations mgr. the Steel div., Ford Motor Co., Dearborn, Mich. This paper is being presented at the Forty-fourth Conference of the National Open Hearth Steel Committee in Philadelphia, April 1961.

with 45,000 cu ft of oxygen per hr. This represented a total input of 250,000,000 Btu per hr.

Total cold charging time on this heat was 32 min. Upon completion of charging, the roof lances were lowered to a point 2 ft above the scrap. The lances were progressively lowered to follow the scrap as it melted down.

Also upon completion of charging, the doors were banked in about 8 min. The hot metal addition was made immediately upon completion of door banking. This early addition of hot metal is one of the significant parts of the practice. In spite of the high firing rates, melting does not progress nearly to the normal degree at the time of the addition, and three ladles of hot metal are required. For the heat under consideration, the total time of addition was 20 min, and the elapsed time from the start of charging to the completion of the hot-metal addition was 1 hr.

Finishing and refining

Immediately after the hot metal addition, the natural gas was turned off the roof lances, and they were lowered as rapidly as melting permitted to a position 4 in. above the bath. This lance level, with 45,000 cu ft of oxygen per hr on each lance, was maintained throughout the remainder of the heat. The lances were never raised in spite of foaming. The velocity of the oxygen at the exit of the lance was 1,000 fps, and the heavy foaming condition appeared to blanket the splash. We feel that this is significant and that higher oxygen flows could be used without excessive damage to refractories.

Scrap protruding through the bath disappeared rapidly after hot metal was added. End firing was gradually reduced after the hot metal addition to a minimum of 2 gal of oil per min. The use of oxygen through end burners was discontinued. Flushing began 30 min after hot metal addition and continued to some extent until bath carbon reached a level below 1 pct C. End firing was virtually discontinued from start of flushing until shortly before tapping. During this period the furnace was operated with maximum draft to control slag temperature.

Throughout this series of experimental heats, fuel usage through end burners has been steadily decreased. It is becoming increasingly apparent in this work that no end firing is required during the refining and finishing stages of the heat. In spite of the low fuel rate on this particular heat, present work indicates that considerable fuel was wasted only because tradition seems to force us to maintain some fuel on the furnace.

The first carbon and temperature were taken 90 min after the hot-metal addition or 2 hr, 30 min after charging was started. The progress of the heat from this point to tapping is shown in Fig. 1. The last carbon check showed 0.17 pct at 159 min after hot metal, and the temperature was 2800°F.

Table I. Heat Cycle on the 400-ton Open-Hearth Furnace

Operation	Time, Min	Total Elapsed Time, Hr:Min
Cold charging	32	0:32
Door banking	8	0:40
Hot-Metal addition	20	1:00
Hot metal to first carbon	90	2:30
First carbon to tap	94	4:04
Tons tapped	427.5	
Output, tph (chg to tap)	105.1	
Fuel, MM Btu/ton	0.723	
Oxygen, cu ft/ton	1533	

Metal analysis: 0.055 pct C, 0.33 pct Mn, 0.011 pct P, and 0.025 pct S

At 172 min after hot metal the temperature was 2830°F, and at 175 min it was 2845°F. At 180 min after hot metal, 6000 lb of hot metal were added. The temperature went up to 2895°F 3 min later, and the heat was tapped 184 min after hot metal.

The total charge-to-tap time amounted to 4 hr and 4 min for 427.5 tons, or a rate of 105.1 tph. Total charge-to-tap fuel was 723,000 Btu per ton, with a total oxygen consumption of 1533 cu ft per ton. The final analysis of this heat was 0.055 pct C, 0.33 pct Mn, 0.011 pct P, and 0.025 pct S.

Throughout this discussion reference has been made only to charge-to-tap data. We feel this is the proper way to evaluate the practice, since the experimental heats were not carried out on a repetitive basis, and we have seen nothing so far that would lead us to believe there is any difference in hearth deterioration between these and conventional heats. It should be emphasized that these heats have been carried on in an experimental manner and certainly a great deal more work is indicated. True, these heats were given special attention, but any open-hearth furnace that travels at this pace will need closer melting attention.

Conclusions

Although the results we obtained were encouraging, each heat produced suggested many additional ideas. Our original work began with a 100-ton heat in a 200-ton furnace, using a conventional limestone and ore charge with 70 pct hot metal. The heat size was reduced because we were concerned with our ability to contain the heat in the furnace during the ore boil with the high oxygen input.

From this we moved progressively to normal heat size, substituting burnt lime for limestone and eliminating the charge ore with a corresponding decrease in the amount of hot metal used. It appeared that this reduction of high heat absorbing reactions tended to reduce the total heat time to an extent that more than offset the additional cold charging required. The elimination of the charge ore also tended to reduce the volume of the flush slag, and as a result, normal yields have been experienced.

As previously mentioned, we attach considerable importance to the early addition of hot metal in combination with high oxygen usage. Considering the total fuel input per ton, it appears that this practice provides for maximum utilization of the chemical heat developed from the oxidation practice.

Our work with roof lances has not been confined to the oxy-gas lance. We have had very good results with oxygen-enriched conventional end burners, complemented with straight oxygen roof lances after hot metal, using the same charging practice. However, we feel that multiple oxy-gas lances introduced through the roof offer a new and more efficient firing method of the open-hearth furnace, and as their development progresses, we feel that they offer the best opportunity for some cost saving design changes in the furnace, as well as the opportunity to take full advantage of raw material prices with a minimum effect on heat time.

The entire picture adds up to the fact that a lot more work has to be done, and it will probably be done more rapidly than we realize. Undoubtedly, open hearths have potential beyond our present vision, and regarding future progress, the question may well be asked, how long will they be referred to as *open-hearth furnaces?*

OPERATING EXPERIENCE WITH OPEN-HEARTH LANCES

For several years the steelmaking industry has been experimenting with the use of oxygen roof lances in open-hearth furnaces. This article describes operating experience with this technique at three plants of Bethlehem Steel Co.

by D. F. Brion, R. F. Urban, and T. B. Winkler

For the past several years Bethlehem has been developing an operating practice for furnaces equipped with roof oxygen lances. The practice has evolved in a stepwise manner, incorporating changes and improvements with each additional lance furnace.

Although certain details of the operating practice are influenced by local plant and individual furnace operating characteristics, the basic principles are applicable to all open-hearth furnaces. This practice, originally developed for furnaces operating with silica roofs, will apply with minor modifications to furnaces equipped with basic roofs.

It has been demonstrated that, with proper adherence to this operating practice, production on open hearth furnaces can be increased from 20 to 50 pct with refractory costs as low as or lower than experienced on conventional furnaces.

Charging

The use of oxygen through lances to supplement the total oxygen supply to a furnace decreases ore requirements, so that a smaller percentage of ore must be charged for any given percentage of hot metal. This decrease can be met either by allowing the ore charge to remain unchanged and increasing the hot-metal charge by 10 to 25 pct or by reducing the charge ore 25 to 85 pct and increasing hot metal and/or scrap charge by the amount necessary to maintain constant metallic charge weight. For either charging method, the limestone charge can be reduced or completely eliminated to insure a desirable melt.

Oxygen usage

Oxygen flow rate per lance varies with furnace sizes and number of lances. As oxygen flow increases, oxygen consumption per ton of steel also increases. Our experience indicates that finish metal-to-tap time—the time during which oxygen is being used—is directly related to oxygen consumption. This is shown graphically in Fig. 1.

Acceptable oxygen consumption per ton for a given furnace depends on furnace design (size of combustion chamber, roof height, type roof, etc.) and capacity of forced air and induced draft fans. Experience indicates that oxygen flow rate and hence consumption, should be maintained at the highest value compatible with the existing conditions to gain maximum furnace production. This consumption at present appears to be in the range of 600 to 800 cu ft per ton, with a minimum of about 400 cu ft per ton.

Oxygen efficiency, or rate of carbon drop at a given flow rate, is affected not only by lance position but also by the mass velocity of the oxygen at the tips of the lance nozzles. For best results, lance nozzles have been sized for high mass velocities. Mass velocity is defined as the weight rate of flow divided by the area of the given cross section. We use lances with multiple nozzles so sized that the mass velocity is 100 lb per sec per sq ft or higher. Fig. 2 shows mass velocity for lances with six nozzles of the indicated size as a function of oxygen flow rate. The oxygen supply line pressure of 100 to 125 psi has generally been sufficient to accommodate the range of practical oxygen flow rates.

The effective use of oxygen is independent of the number of lances through which the oxygen is delivered as long as the mass velocity of the oxygen is 100 lb. per sec per sq ft or over. However, when the oxygen consumption exceeds about 400 cu ft ton, it has been our experience that more than one lance is needed to control splash and fume to prevent excessive refractory damage to furnaces of normal roof height.

The roof lances are lowered into the furnace immediately following the hot metal addition. If there is scrap under the lances, they are lowered to within 3 to 4 in. of the scrap. As fast as the scrap is melted

D. F. BRION and T. B. WINKLER are with the Research Dept. of Bethlehem Steel Co., Bethlehem, Pa., and R. F. URBAN is asst. to supt., Open Hearth and Bessemer, at the Sparrows Point plant.

Table I. Furnaces Equipped with Oxygen Roof Lances

Furnace	Capacity NT/Heat	Roof	No. of Campaigns	No. of Lances	Oxygen Flow cfh/Lance
		LACKAWANNA			
34	270	Silica	9	1	25-35,000
33	270	Silica	4	2	25-30,000
22*	390	Silica	2	2	35,000
22	390	Basic	1	2	35,000
23*	390	Silica	1	2	40,000
		SPARROWS POINT			
75*	385	Basic	3	2	35-50,000
96	390-420	Silica	1	2 or 3	35-50,000
96	390-420	Basic	1	1, 2 or 3	50-140,000
94	390-420	Silica	2	2	50,000
		JOHNSTOWN			
62	185	Basic	2	2	20-40,000

* Bifurcated Furnaces.

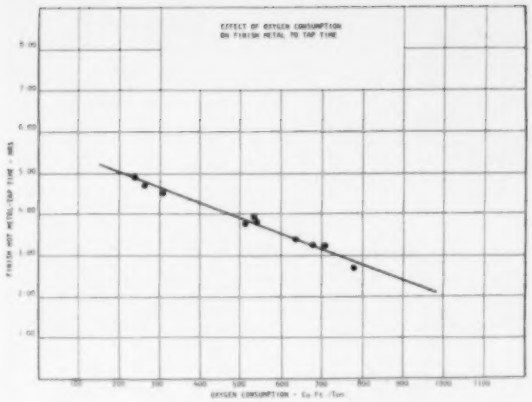

Fig. 1—Effect of oxygen consumption on finish metal-to-tap time.

the lances are lowered to the final operating position which is no greater than 8 in. and preferably 4 in. above the slag-metal interface. This means that in the early part of the heat, especially during the flush, the lances are being operated in the slag. Operating at this position increases oxygen efficiency, reduces splash and fuming, and minimizes slag foaming. In order to position lances accurately, most furnaces are equipped with an indicating device.

The oxygen lance furnace is operated in the same manner as a conventional furnace from start of charge to finish metal. As soon as the oxygen lances are lowered into the furnace at finish metal, the fuel rate is reduced below the normal rate. On silica roof furnaces, fuel is adjusted according to the roof temperature. In some furnaces this is indicated by radiation pyrometers sighted on the key of the roof at the knuckles. The temperature is kept 75° to 200°F below that of a conventional furnace during the same period.

The exact fuel rate is dictated not only by roof temperature but also by the physical proportions of the furnace, available induced draft, combustion air capacity, etc. On most furnaces the fuel rate is reduced to about 70 pct of the amount used on conventional furnaces until the flush is flowing freely and then reduced to approx 50 pct of normal. Later in the heat it is often necessary to make further reductions in fuel or to shut it off completely for short periods of time to keep from exceeding temperature limits. On most furnaces only liquid fuel is used during the blowing period.

Although fuel input is reduced during oxygen lancing, the combustion air level is maintained at a rate which insures several pct of free oxygen, preferably not less than 5 pct, in the exhaust gases measured in the downtakes at floor level.

Furnace pressure is regulated well below normal operating levels. In normal practice it is customary to maintain a positive pressure at the wicket hole on two to four outgoing doors. On lance furnaces it is desirable to have draft at the wicket holes of all doors. For example, the normal operating furnace pressure on the Sparrows Point furnaces is 0.10 to 0.11 in. of water, but on the oxygen lance heats the furnace pressure is controlled at 0.04 to 0.05 in. of water.

Our experience to date has shown that oxygen lance furnaces which have operated with strongly oxidizing atmospheres, adequate draft, and low roof temperatures have exhibited very favorable rates of refractory wear.

Furnace practice

More care needs to be exercised on oxygen furnaces during the flush period to prevent excessive metal losses and consequent loss in yield. However, if the flushing notch is kept wide and shallow, this does not become a serious problem.

At the end of the flush, an addition of two pans of burnt lime is made, and the first carbon test and bath temperature are taken. Additional carbon tests and bath temperatures are secured at 15-min intervals throughout the remainder of the heat. Ore additions are used to control bath temperature; they are made according to carbon-temperature schedules posted at the furnace. Further burnt lime additions are made

Table II. Typical Performance of Open Hearths With Oxygen

Furnace	Roof	Tap to Tap, Hr	Ton/Hr	Oxygen Cu Ft/Ton	Fuel, MM Btu/Ton	Roof Life	
						Total	Unit
		No. 3 O.H. Shop—Lackawanna—270-Ton Furnaces					
34	Silica-1 Lance	8:52	29.5	390	2.5	216	123
33	Silica-2 Lance	8:23	31.2	730	2.2	273	115
Shop	Silica	10:23	25.6	20	3.2	226	125
		No. 4 O.H. Shop—Sparrows Point—420-Ton Furnaces					
94-96	Silica	8:01	50.9	635	2.6	397	130
Shop	Silica	10:30	37.7	0	3.6	265	127
96	Basic	7:23	55.1	595	2.6	344	278
91	Basic-No Oxygen	9:49	40.2	0	4.1	641	444
		Johnstown—185-Ton Furnaces					
62	Basic	7:08	25.9	890	2.6	249	357
Shop	Silica	10:38	17.1	10	3.9	245	103

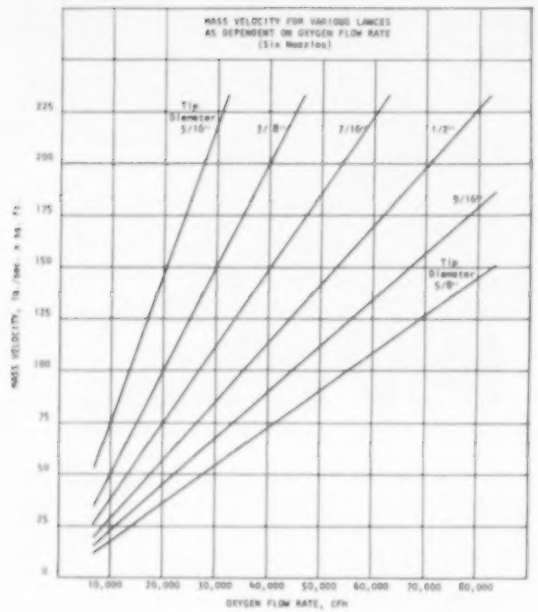

Fig. 2—Mass velocity for various lances vs oxygen flow rate.

as necessary to insure a good slag.

As reported by the metallurgical departments of Bethlehem's various plants, there is no evidence of measurable deterioration of quality on heats made using roof lances. Comparison of heats made on specific furnaces with and without the use of roof lances showed a negligible difference in the number of heats produced outside the specified analysis range. This still appears to be a function of the melter's control rather than the effect of oxygen blowing.

It is our opinion, substantiated by experimental data, that the quantity of oxygen and the length of the blow, per se, have no effect on deoxidation practice. With oxygen lances, it is much easier to go below the minimum desired carbon at tap than it is with conventional heats using ore. It is the carbon level in the bath at tap which controls the oxygen content of the metal, which, in turn, controls the deoxidation practice. A low carbon content means a high oxygen content. Therefore, in making low carbon steel with oxygen lances, it is necessary to control the oxygen blow closely to avoid a low tap carbon and consequent high oxygen content.

Summary

The operating practice as described applies, in general, to all furnaces equipped with roof oxygen lances. There will be variations in the practice which are dictated by furnace design size and local plant conditions. However, the features of the practice listed below serve as a guide in establishing the specific practice for individual furnaces.

1) Modify the charge to reduce the ore to hot metal ratio;

2) Lower lances immediately after hot metal to a position approx 4 to 5 in. above the slag-metal interface;

3) Maintain close control of flush to avoid metal loss and resulting low yield;

4) Use the maximum oxygen flow rate compatible with furnace design and refractory wear;

5) Use liquid fuel at a reduced rate during oxygen blowing;

6) Equip furnace with temperature indication so that it can be operated reliably at reduced roof temperature;

7) Carry high excess air in the waste gases (5 pct O_2);

8) Operate with low furnace pressure (draft at all doors);

9) Make burnt lime additions early (at end of flush) and thereafter as necessary to meet chemical specifications;

10) Take furnace tests and temperatures at 15-20 min intervals;

11. Use a carbon-temperature schedule for ore additions; and

12) Stop oxygen blow as near tap carbon specification as possible. Do not overblow for temperature.

It is felt that with this practice the production rate on present furnaces can be raised to the limit of the shop facilities for servicing the furnace (charging, pouring heats, etc.) without increasing refractory costs.

Discussion

Eight furnaces in three separate plants of Bethlehem Steel Co. are equipped with oxygen roof lances. A list appears in Table I. These furnaces have been used to evaluate the use of roof lances as applied to the individual characteristics of the shops in which they are located. From this table it is evident that variations in furnace size, number of lances, oxygen flow rate, and type of roof brick have been tested.

Typical performances of oxygen furnaces at Lackawanna, Sparrows Point, and Johnstown for 1959 and 1960 are shown in Table II. A comparison of No. 33 and No. 34 furnaces at Lackawanna indicates the improvement in heat time accomplished by doubling the rate of oxygen input by virtue of using two lances instead of one. This is done at the expense of twice the oxygen consumption, but with a balancing saving in fuel consumption. Silica roof life with either oxygen practice is about equal to that without oxygen.

The experience at Sparrows Point demonstrates the improvement in production rate that can be accomplished on an oxygen furnace through the use of a basic roof compared to a silica roof. This is the direct result of the ability to use higher maximum firing rates with a basic roof. As at Lackawanna, the silica roof life on oxygen furnaces has been at least as good as on conventional furnaces. However, the basic roof life has been disappointing.

At Johnstown the 50 pct improvement in production rate has been the result of the combined benefits derived from oxygen roof lances and a basic roof. Here, too, the basic roof life has been disappointing. This may be the result of striving for a good production rate by firing the furnace harder, allowing higher furnace pressure, and permitting higher roof temperature than is compatible with best refractory life.

Most of our experience has been gained on silica roof furnaces and most of our effort has been concentrated on the development of a satisfactory operating practice for this type furnace; we feel we have been successful. Our experience on basic roof furnaces is limited and our practice needs refinement.

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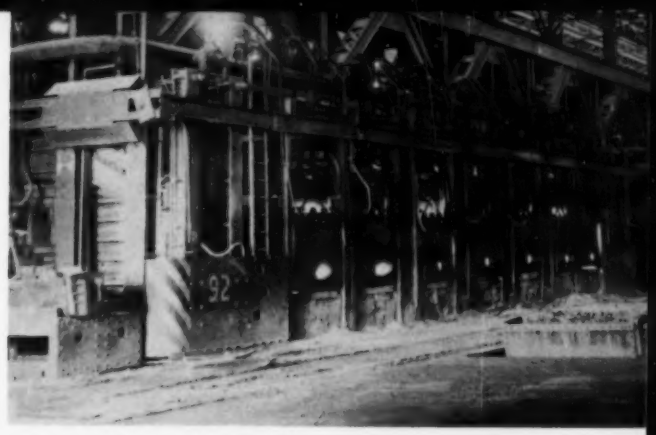


FUTURE OF THE OPEN HEARTH

The advent of basic oxygen steelmaking processes has aroused concern about the future of the open hearth process as a prime producer of steel. This paper reports what is being done today, and the probable future of the open hearth process.

by A. K. Moore

With the advent of the basic oxygen steelmaking processes, the future of the open-hearth furnace has become the subject of considerable speculation. It is the intent of this paper to assess what is happening today and to predict the future of the open-hearth process.

Most evaluations of steelmaking processes have considered quality and range of product, capital costs, raw material requirements, and operating efficiencies. With regard to quality, there is little or no difference today between these processes. Steels with lower sulfur contents are usually produced by the basic oxygen processes because of the absence of sulfur-bearing fuels. These processes also produce lower nitrogen steels than the open hearth process; however, temperatures are more readily controlled in an open hearth operation, and on the average, the process produces steels with a somewhat cleaner microscopic background. At any rate, either process produces steels that are adequate for the fabricator's needs. The open hearth process currently has a slightly wider range of products, but proponents of the basic oxygen processes are quick to point out that developments are increasing the range of steels which can be produced by these methods.

A. K. MOORE is superintendent of open hearths, The Steel Co. of Canada. This paper is based on an address to the sectional meeting of the NOHC, Buffalo, N. Y., November 1960.

One important consideration in the comparison of both processes is capital costs. It is generally agreed that, on a ton-for-ton basis, a basic oxygen steelmaking process can be installed at a lower cost than an equivalent open-hearth shop. However, it should be noted that this comparison includes only the steelmaking plant and the necessary oxygen plant, and not the equipment necessary for providing a hot-metal charge. When considering all of the iron and steelmaking plant necessary to produce equal tonnage, an open hearth plant appears to be more economical to install.

At the Steel Co. of Canada a conservative estimate indicates that open hearth capacity can be expanded by a minimum of 1-million tons annually at a cost of some $25 million if operated on a 45 pct hot-metal charge. A similar expansion for a process requiring a 75-pct hot-metal charge would result in a total expenditure of over $50 million. However, it should be pointed out that in plants already having excess hot-metal capacity it would be more economical to install a basic oxygen process.

An important advantage of the open hearth process has been the ability to maintain its productivity

using a wide range of raw materials. Modern open hearth shops can operate on a raw material range of 40 to 70 pct hot-metal charge, while basic oxygen process usually experience difficulties when utilizing hot-metal charges of less than 70 pct.

Sufficient scrap is presently generated on the North American continent to supply enough raw materials to operate on a 50 pct scrap charge. Since basic oxygen processes operate on a high hot-metal basis, its wide-spread installation could conceivably result in a *build-up* of scrap. The excess scrap may be either sold abroad, or be permitted to collect until the cost of gathering and preparing sufficient quantities would be econo.nically attractive. Presently, there is little difference between the cost of producing hot metal and price of scrap; however, there is little reason to believe that costs for the production of hot metal will be reduced significantly in the near future.

It is generally agreed that an open hearth utilizing the same amount of hot metal as a basic oxygen process, and operating with normal fuel practice, has production costs which exceed those of comparative basic oxygen process. This is the obvious disadvantage of the open-hearth process —one which steelmakers must overcome in order to maintain the prime position of the open hearth as a steel producer.

Oxygen usage

Steelmakers have been experimenting with oxygen injection in the open hearth for many years, and were content to leave it on an experimental basis, until the basic oxygen processes shocked them out of some degree of complacency. Now, most producers have started serious programs with oxygen blowing in the open hearth. Naturally, the majority have approached this problem with a wary eye on repair and maintenance costs. Some producers have found that they have had to limit oxygen velocities and input rates to approx 1000 ft per sec and 40,000 to 50,000 cu-ft per hr, while maintaining a lower but appreciable fuel rate throughout the operation. These methods are providing tap-to-tap times on the order of 6 to 7 hr. In one plant at least, the refractory costs are as low as, if not lower than, those in the basic oxygen process. Unfortunately, the productivity obtainable with the limited use of oxygen is not sufficient to compete with the pneumatic processes.

A minority of producers have chosen to conduct experimentation with much higher oxygen inputs and velocities. Some have supplemented fuel input during scrap melting with a mixed fuel-oxygen lance injection to allow more rapid charge completion. It is believed that higher productivity—less than 4 hr tap-to-tap times—can be attained with less than 50 pct hot-metal in the charge, if proper attention is paid to materials handling design.

Refractory wear is still the major problem to be overcome in increasing the productivity of the open hearth. To date, no one on this continent has attempted to run a furnace with oxygen rates which would confine the use of fuel to the scrap melting period, although something of this nature is being practiced in Japan. This is a necessary step if productivity is to be increased and refractory wear reduced. If fuel is utilized for scrap melting only and an oxygen lance used for the balance of the work, an appreciable decrease in refractory wear should be obtainable with various other relatively minor adjustments.

Long range possibilities

Eventually, open hearths may be enclosed by something on the order of the Maerz-Boelen design. No checkers would be required because the fuel required during scrap melting will be burned with the oxygen supply. Any liquid fuel required to finish higher carbon heats would also be burned with the oxygen and the products of combustion would pass through a downtake and slag deposition chamber to a boiler, precipitator, and stack. This might appear to be a dream open hearth but it may be a reality before too long.

Concerning its long term future, the traditional open hearth operation, dependent on fuel alone for heat-producing energy, is a *dead duck*. Present competition has resulted in activities which are opening up new horizons for what will probably be called the open-hearth process, although within 20 years, there may be little or no more difference between the open hearth and the basic oxygen furnace, than there is today between the stationary and tilting open hearth.

The important thing is that steelmakers must shake off the habit of thinking about open hearths, and in particular, open hearth shops, in terms of what they are, instead of what they would like them to be. Generally speaking, materials handling capacities are too low. Experience at our plant has demonstrated that charging box-charging machine handling can be adapted to a heat cycle of less than 4 hr tap-to-tap time. It would probably be more difficult to adapt a 50 pct cold charge to a basic oxygen process than to adapt this handling equipment to rapid heat cycles. As far as the pit side is concerned, the open hearth shop with a single runway pouring isle is obsolete. Pit sides will have to be designed to handle the rapid heat cycles of the furnaces. Furnace sizes will be determined by handling equipment with each plant determining its heat size for maximum flexibility of its own market. If these things are accomplished, the open hearth will be able to maintain the maximum convenient flexibility in a single steel producing process.

Conclusions

It is hard to picture open hearth capacity losing its premier position in steelmaking during the next 10 years simply because so much capacity exists which is amenable to productivity improvement. However, it is possible to draw the following conclusions:

1) Basic oxygen processes will replace and add to obsolete open hearth capacity for some time in plants based on a high hot-metal charge capacity;

2) The obsolence will be checked to some extent by the improvement of productivity in open hearth shops which have the materials-handling ability to accelerate the process with oxygen blowing;

3) Plants unable to adapt to a high hot-metal charge will exploit the conversion of the open hearth from a fuel process to an oxygen process with reasonable success; and

4) Developments of this type will provide a wide range process of competitive productivity and operating cost which, in the course of time, should be attractive for expansion plans.

METHODS OF REDUCING IRON ORES

Summary of a symposium by this title presented by The Electrochemical Society in Chicago, May 1960; it is written by an expert on the subject who participated in the symposium.

Translated from a Report by J. Astier

The 200 to 300 persons in attendance at the symposium, *Methods of Reducing Iron Ores*, presented by the Electrochemical Society as a part of its 117th meeting, represented almost all firms and individuals active in the development of direct iron-ore reduction processes. Many of these persons presented papers on processes which they had developed. There were four papers on fluidized bed techniques, an equal number on kiln processes, two on gaseous reduction at high temperatures, and six on electric furnace processes utilizing a pre-reduced charge. In addition, there were eight papers of a general nature, and O. R. Rice of Koppers Co. presented a defense of the blast furnace in a paper entitled, *How Are the Blast Furnaces Doing?* At a later point in the symposium, a panel was organized in order to answer questions from the audience; this permitted discussion of a number of subjects such as investment, energy balances, and production costs.

Not all direct iron ore reduction processes were discussed, and mention should be made of the batch-type process in a reactor such as that developed by Madras and applied to a plant being built in Arizona[1] and the HyL process in operation at a Mexican steel plant.[2]

Fluidized bed processes

Papers were presented on the H-Iron process,[3, 4] the Nu-Iron process,[5] the Esso Research-Little (ERL) process, and techniques developed by Battelle Memorial Institute. In order to be complete, mention should also be made of several fluidized-bed processes not discussed in Chicago. One of these is the Novalfer process being developed at Toulouse, France in a 10-tpd pilot unit. The process uses hydrogen produced from natural gas for the reduction of rich iron ore. It is a continuous one-stage reduction process at 600° to 700°C preceded by preheating. Other fluidized bed processes not considered at the symposium were the Stelling process using carbon monoxide,[6] the CO-C-Fe process being studied by Phoenix in Germany in a 5-tpd unit, and Soviet studies of which relatively little is known.

Interesting information on particle size was revealed in two papers. Stotler and Lubker, describing the H-Iron process at Alan Wood Steel Co., stated that magnetite concentrates of 20 to 200 mesh size and mill scale between 80 and 325 mesh were treated. They admitted that the small size of the mill scale had caused some difficulties, but the situation can be remedied, in part, by augmenting the molecular weight of the gas, and in practice by utilizing a mixture of nitrogen and hydrogen. According to R. W. Hyde, in describing the ERL process, means exist for working with fine particles by making a closed circuit between the cyclone and the bed, but few details were given on this subject.

Probably one of the most interesting papers presented at the symposium was that of Stephens and Langston of Battelle Memorial Institute.[7] They described experimental work on the fluidization of −325 mesh concentrates; it was financed by Jones & Laughlin, Cleveland Cliffs, Wheeling Steel, and Inland Steel. Fluidization was conducted at temperatures high enough so that fine particles of reduced metal ($-150\,\mu$) agglomerated into drops of about 3 mm size. When these pellets were sufficiently large, they migrated to the bottom of the reactor where they could be extracted.

In Table I the conditions of fluidization of the various processes are summarized.

On the economic side, figures cited for the ERL process showed a capital cost of $37 per annual metric ton for a plant of 1000-tpd capacity; this

Table I. Conditions of Fluidization for Iron Ore Reduction Processes

Process	Temp, °C	Gas Velocity, m/sec	Pressure, kg/sq cm	Bed thickness, m	Particle size, μ
H-Iron	480-550	0.3-0.8	28-35	—	40-800
Nu-Iron	650-700	0.4	atm	3.6	0-800
Novalfer	600-700	0.2-1.0	atm	—	40-1000
ERL	800-850	—	atm	—	0-2000
Battelle	760-900	3-10	atm	0.9	0-100

J. ASTIER is head of development, Ironmaking div., IRSID, Maizieres-Les-Metz, (Moselle), France.

figure does not include costs for boiler and power plant. Figures given for other fluidized bed processes installed in a plant of comparable size were not less than $40 per annual metric ton, and this is probably too low for a plant on a new site.

Per metric ton of product, the ERL process consumes 400 to 450 cu m of natural gas, 1 ton of steam at 370°C and 4 kg per sq cm, 35 kw-hr, and 0.172 man hours. Values for the other processes are available; for example, a 1000-tpd H-Iron plant would consume per metric ton of output: 450 cu m of natural gas, 80 kw-hr, and 0.28 man hours.

Concerning the economics of these processes, J. C. Agarwall of U. S. Steel Corp. dropped a bomb-shell by saying that the studies by his firm showed these processes to be uneconomic in any location in the United States. The essential reason is the cost of reducing gas, whether it be hydrogen or a mixture of carbon monoxide and hydrogen. Nevertheless, U. S. Steel is continuing its experimental work, especially in the area of the reforming combustibles. This economic factor explains why developers of these processes are orienting themselves more and more toward the utilization of cheaper ores.

In relation to the economics of these processes, mention should once again be made of the work of Stephens and Langston of Battelle. This work has opened an original path for the reduction and agglomeration of fine concentrates in a fluidized bed. Such concentrates are often very difficult to agglomerate.

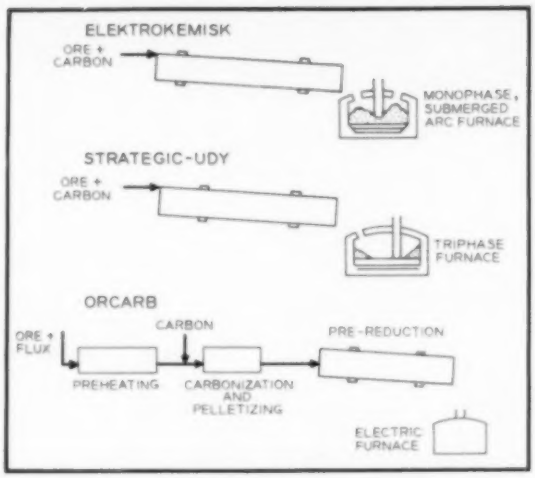
Kiln processes

H. Freeman described his co-current kiln reduction process which is undergoing pilot-plant tests on a 10-tpd basis at Cap-de-la-Madeleine, Quebec, Canada. The plant includes a 4 x 33-ft kiln with a pelletizing installation. Reduction of high-grade material requires 2 hr for 0.75-in. pellets and more than 3 hr for pellets of twice this size. Temperatures are maintained at about 1000°C. Energy requirements per metric ton of product are 600 kg of coke and 300 kg of fuel oil, in total about 19 million Btu.

J. S. Breitenstein gave information on some improvements in the RN process;[8] these included attempts to increase the capacity of the kiln, the use of continuous-grate preheating, and the installation of a coking unit to produce coke and gas at the Birmingham, Ala., pilot plant. It should be noted that the RN process, with the addition of a continuous grate and the utilization of pellets, appears to present many similarities to the Allis-Chalmers Agglomeration-Reduction (ACAR) process.

Reduction to liquid metal

R. Wild of the British Iron and Steel Research Assn. in a paper entitled, *Some Considerations of Fuel Requirements for Iron Ore Reduction* mentioned the Flame Smelting process in which partially reduced ore is introduced into a pulverized coal-oxygen burner where it is rapidly converted into molten metal and slag. Waste gas from the high-temperature reactor is used to preheat and partially reduce the raw ore entering the system. He indicated that developments were moving in the direction of a total coal consumption of 1100 kg per metric ton of metal.



Schematic diagrams of the Elektrokemisk, Strategic-Udy, and the Orcarb processes for iron ore reduction in an electric furnace.

R. L. Cavanagh of the Ontario Research Foundation indicated that his Jet Smelting process[9] was moving toward the utilization of a pre-reduction step on a continuous grate. The present state of development of the Jet Smelting process provides for a two-stage unit. Ore is introduced into a high-temperature burner utilizing natural gas and oxygen in the ratio of one to two. The presence of iron ore, brought to a high temperature by this primary burner, facilitates cracking of the natural gas. Secondary natural gas is introduced for the purpose of creating a reducing atmosphere. In this process it is preferable to make a carburized metal in order to reduce temperature requirements and have less difficulty with refractories. The use of oxygen diminishes the total volume of gas leaving the furnace, and at the same time, reduces the quantity of dust entrained.

A heat balance in terms of million Btu per net ton of 95 pct Fe shows that of the heat available (11.4 million Btu), 8.98 or 79 pct is transformed into the sensible heat of the exhaust gas. Fuel value of the exit gas is 204 Btu per cu ft which could supply the necessary energy for oxygen production with excess gas used for preheating and pre-reduction. For 1 ton of 95 pct Fe metal, 57,500 cu ft of methane and 45 cu ft of oxygen are required, with exhaust gas amounting to 176,000 cu ft. The amplitude of the problem posed by the utilization of the residual gas is evident. It should be noted that perhaps 30 pct of the reduction is made in the liquid state in the slag bath and at the contact with the metal. Investment costs for a 100-tpd plant at, or near, a mine site in Ontario are about $60 per net ton per year with production costs set at $61.60 per net ton.

Electric furnace with pre-reduction

Unfortunately, no paper was presented on the Dwight-Lloyd McWane process[10] or the important Soviet work in this domain. A general paper covering the field was presented by N. H. Keyser of Battelle Memorial Institute under the title, *Tech-*

nical and Economic Factors to be Considered in the Electric Furnace Reduction of Iron Ores. Specific processes discussed were a combination kiln and electric arc furnace by F. C. Collin of Elektrokemisk,[11] the Strategic-Udy process, the Orcarb process utilizing pellets containing ore and coke, the double-hearth induction furnace of de Sy,[12] and a combination fluidized-bed and electric arc furnace being developed by Demag at Aachen, Germany.

Collin gave results of operations on classical electric iron smelting furnaces using self-fluxing agglomerate which approached a consumption of 2000 kw-hr per net ton. He showed results obtained at the Elektrokemisk pilot plant at Fiskaa, Norway, where a charge was made up of a self-fluxing mixture of magnetite concentrates. For a cold charge, electrical requirements per net ton of pig iron varied from 2060 to 2150 kw-hr and for a charge heated to 800°C from 1580 to 1700 kw-hr. With these results, one might well ask why additional work is not pursued in the direction of the utilization of agglomerates charged into the furnace at the highest possible temperature.

M. C. Udy presented new cost estimates for the Strategic Udy process and indicated a certain number of forthcoming industrial installations for the process. It is certainly one of the processes being most discussed.

On the Orcarb process, C. E. Lesher showed a flow sheet which appeared somewhat more complex than for the other processes, although certain advantages are apparent. One is the absence of difficulties in the electric furnace because of the utilization of pellets containing prereduced ore (a conductor) and coal cokified in place. A pilot plant is now in service, and it is probable that more will be heard about this process in the near future.

Professor de Sy recalled the principles of his double-hearth induction furnace method and expressed his desire to construct a pilot plant to study the economic aspects of the process.

Pre-reduction in a shaft furnace was discussed by Collin with reference to experimental work being undertaken at Fiskaa, Norway. In the shaft furnace, pellets are heated in a reducing atmosphere to a temperature between 600° and 900°C for about 1 hr. In tests with Sydvaranger magnetite concentrates, 290 kg of carbon was used per metric ton of pig with electric requirements amounting to 1340 kw-hr. Pre-reduction was 70 to 75 pct at a temperature of 800°C. In a second series of tests, hematite ore was used; carbon requirements per metric ton of pig iron were 260 kg and 1270 kw-hr was required in the electric furnace. The degree of pre-reduction was 83 pct with 700°C maintained in the shaft furnace.

In regard to pre-reduction on a continuous grate, H. Walde of Demag in Germany pointed out that his firm was engaged in this development. The idea of reducing pellets on an agglomeration grate is quite tempting, but its economic realization is not an easy matter. Permeability and segregation are two problems, and high efficiency of carbon utilization in a later reduction step appears difficult to attain.

It is evident that these processes and this research on the utilization of pre-reduced material in an electric smelting furnace should succeed on an industrial scale. One favorable factor is the cost of investment for these processes which is lower than for a classic blast-furnace plant with coke ovens and ore preparation facilities. But it should be noted that the differential in capital costs is not the same when the cost of power generating facilities is included. Another favorable factor is the probable long-run decrease in the cost of electrical energy compared with solid, liquid, and gaseous fuels. A third factor, is that these processes are more applicable to small tonnages on the order of 500 to 1500 tpd than are classical techniques.

Conclusions

It is evident that there now exist a number of processes which have been sufficiently developed in pilot plants to permit their utilization on an industrial scale without undue risk. But the majority of these processes scarcely permit the construction of large units on the scale of the modern blast furnace. This is obviously an important limitation, but it may also be an advantage in cases where a small plant is desired.

The economic question is a difficult one. Investment and production costs are on the same order for many of these processes, and the question is whether or not they can be competitive with classical processes. These processes must compete—at least in the industrialized areas—with present day blast-furnace developments, such as the injection of gas and charging of 100-pct self-fluxing agglomerate. These and other techniques permit a 50-pct increase in the capacity of many blast-furnace installations without the installation of additional furnaces or coke ovens.

A fourth conclusion pertains to the present tendency to use lower cost ore to render these processes competitive. This practice is scarcely economic, since the enrichment of reduced ore in the solid state is not always simple or inexpensive, and the melting of low-quality sponge or other reduced material imposes a heavy load on an electric furnace.

On the overall balance it can be concluded that these direct iron-ore reduction processes do have a distinct advantage where the economic factors are right and the desired level of output is not great.

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TACONITE PELLETS IN THE BLAST FURNACE

A summary of a ten-year test program utilizing pilot-plant taconite pellets in experimental and commercial blast furnaces, this paper presents operating data and results of this program, as well as results obtained in recent years with commercial taconite pellets.

by W. E. Marshall

Although the results obtained by the use of taconite pellets in blast furnaces are by now known throughout the steel industry, there has been no published report on this subject. The purpose of this paper is to collect and present the results of a number of blast furnace tests that were carried out during the past decade prior to the construction of the E. W. Davis works of Reserve Mining Co. In addition, some of the results obtained in regular operations during more recent years, using the commercial taconite pellets, are presented.

The first test was conducted in 1948 on the experimental blast furnace of the US Bureau of Mines at the Minnesota Mines Experiment Station in Minneapolis. Subsequently, a pilot shaft furnace pelletizing plant was installed at Ashland, Ky., to produce large quantities of pellets. Blast furnace tests were made on Armco's hand-charge, 13-ft hearth diam furnace in 1950 and 1951. Problems and difficulties associated with the operation of shaft pelletizing furnaces at Ashland and later at the Babbitt, Minn., pilot plant led to the decision to produce pellets on a horizontal moving grate machine. Pellets from such a plant were first made at Babbitt and were tested on Armco's 28-ft diam furnace at Middletown, Ohio, in 1954. Other tests of short duration were made at Ashland on the 27-ft diam Bellefonte furnace in 1955 and at Middletown in 1956 and 1957. Since that time, no specially organized tests have been made, and observations have been limited to the regular operating records.

Test at Minneapolis—1948

Some of the technical data obtained from digging out the Minnesota experimental furnace after the test period was over, were published in 1951.[1] However, none of the operating results were given in that paper.

The little furnace had a hearth diameter of 3 ft and a height of 26 2/3 ft, measured between the tuyeres and the closed bell. Approx 132 net tons of pellets were used in this furnace—about half were made from Benson concentrate and the other half from various smaller batches of taconite concentrate produced at the Experimental Station. The small batches of pellets—accumulated over a long time—varied in chemical analysis and physical properties. However, these were the only pellets available, since there were no facilities for producing large quantities of pellets at that time.

This test was divided into seven periods, labeled A to G. The first six periods were 44 hr long. The data for the seventh period covered only the first 31 hr due to troubles that developed. The blast was heated with a stainless steel heat exchanger. Sometime during the test, a weld cracked, and it became obvious that all the measured wind at the blower was not reaching the furnace. Therefore, blowing rates were calculated by the carbon balance method. The lowest blowing rate was 490 cfm for Period D and the highest 606 cfm for Period E.

The most interesting operating data are shown in Table I. The tons of iron per day have been adjusted to a constant blowing rate of 555 cfm because this was the rate for Period A when the burden was all ore.

As the percentage of pellets increased, the coke rate dropped from 2396 to 1443 lb per NTPI (net ton pig iron); the production increased from 5.68 to 10.00 tpd; the $CO:CO_2$ ratio dropped from 2.51 to 1.47; the slag volume decreased from 1300 to a minimum of 746 lb per NTPI; and the average blast temperature for the seven periods ran from a low of 980°F to a high of 1059°F. Flue dust was 25 lb per NTPI during the 100-pct pellet periods and 8 lb per NTPI for the other periods. The amount of dust produced was small because of the low blowing rates, but the difference was large enough to be significant. Thus, from the beginning it was indicated that pellets should be abrasion resistant and free from fines.

The iron in the burden varied from 53.9 pct for an all-ore charge to 62.3 pct for an all-pellet charge. Although this constituted an increase of only 15.6 pct iron in the burden, production increased approx

W. E. MARSHALL is with Armco Steel Corp., Middletown, Ohio. This paper was presented at the 1961 AIME Annual Meeting in St. Louis.

[1] K. C. McCutcheon, W. E. Marshall, and H. C. Barnes: Procedure Used in Quenching and Digging Out a Blast Furnace and Some Results, AIME, Blast Furnace, Coke Oven, and Raw Materials Proceedings 1951, pp. 200-227.

70 to 76 pct and the coke rate decreased 36 to 40 pct. These improvements are a result of the lower $CO:CO_2$ ratio attained with the pellet burden. A decrease in this ratio was expected, but the magnitude of the decrease was surprising. None of the people involved had ever observed a $CO:CO_2$ ratio as low as 1.47, and it was wondered whether this would occur on a commercial furnace operating at high blowing rates.

As a result of this test, the following conclusions were drawn in 1948:

1) In a small furnace, pellets can be used to make 100 pct of the burden or in any lesser percentages desired when mixed with lake ores;

2) The superior chemical analysis of pellets results in lower coke rate and higher production. A considerable part of the large percentage increase in production is very likely due to specific characteristics of a very small furnace. Such a large percentage increase cannot be expected from a large furnace;

3) Hanging occurred in about the same degree, regardless of the percentage of pellets in the burden, and made slipping necessary;

4) Pressure drop measurements indicated that when hanging occurred, the resistance to gas flow increased principally in the bosh and not in the upper part of the stack; therefore, it appeared that hanging may be due to plastic deformation and agglomeration in the furnace where the temperature is high enough to soften the sponge iron but not high enough to cause free running; and

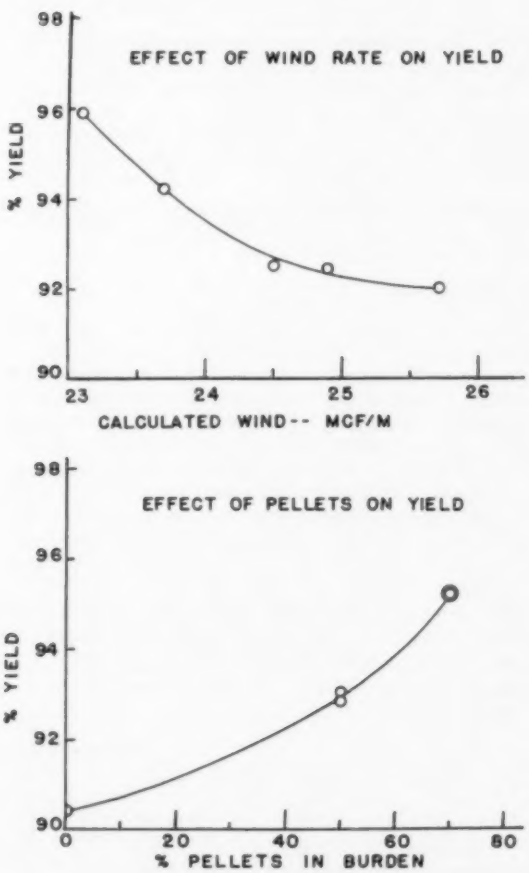
5) Finally, it appears from this experiment that there are no serious problems in using pellets in the blast furnace, if they are of good physical quality. Special attention should be given to hardness and strength.

It is clear from the second conclusion that the group performing this experiment did not foresee the full potentialities of pellets in 1948 and were seeking some hidden explanations for the extraordinary improvements in production and coke rate. Actually, a $CO:CO_2$ ratio of less than 1.50 was not attained on a commercial furnace until 1958.

Ashland test—1950

After the test at Minneapolis, a shaft furnace for hardening pellets was built at Ashland and a stockpile of pellets accumulated for a test on a larger blast furnace. Since a plant did not exist for producing taconite concentrate, these pellets were made from Benson concentrate purchased from Jones & Laughlin Steel Corp. The blast furnace used is designated as Ashland No. 1 and is roughly classed as a 400-ton furnace. It has a hearth diam of 13¾ ft, and is approx 60 ft from tuyeres to the big bell. The test was divided into four periods of 10 days each. Between successive periods, a two-day transition period was allowed to avoid overlapping effects as the furnace adjusted to its new burden. Operating results for the 1950 Ashland test are shown in Table II.

For a long time, the average blowing rate used on No. 1 furnace had been 76 rpm of the piston-type



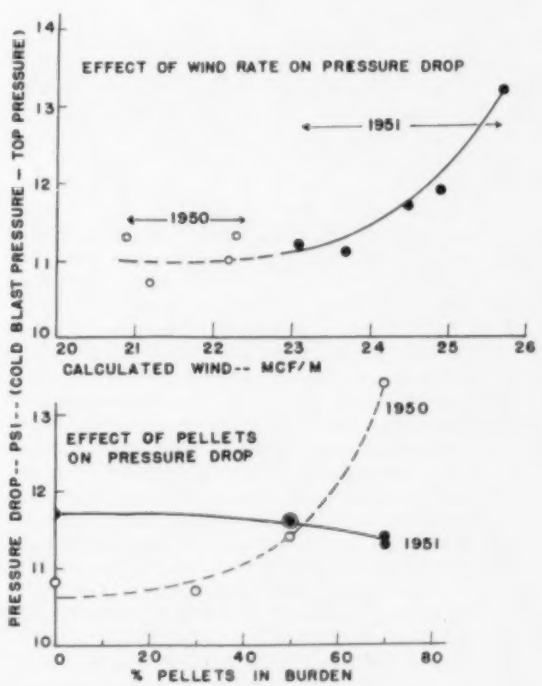


Fig. 1—Right, Effects of wind rate and pellets in burden on yield. Fig. 2—Above, Effects of wind rate and pellets in burden on pressure drop.

Table I. Operating Data for Blast Furnace Test at USBM Minn. Mines Experimental Station—1948

Period	Pellets, pct	Blast Temp, °F	Blowing Rate, cfm	CO/CO_2	Coke Dry, lb/NTPI	Prod[a], tpd	Change from A, pct	
							Coke	Prod
A	0	1089	555	2.51	2396	5.68	Base	Base
B	30	980	538	2.15	2084	6.73	−13	18
C	30	1031	572	2.35	2133	6.68	−11	18
D	60	1025	490	1.90	1818	7.75	−24	36
E	60	1020	606	1.88	1872	7.77	−22	37
F	100	1015	578	1.61	1523	9.63	−36	70
G	100	967	597	1.47	1443	10.00	−40	76

[a] Adjusted to blowing rate = 555 cfm.

Table II. Operating Data—1950 Ashland Test

Burden No.	Pellets, pct	Blast Temp, °F	Blowing Rate, cfm x 10^3	CO/CO_2	Dry Coke, lb/NTPI	Prod, tpd	Change from 1, pct	
							Coke	Prod
1	0	1278	22.3	2.16	1720	375	Base	Base
2	30	1265	21.2	2.03	1585	395	−8	5
3	50	1307	22.2	1.98	1572	428	−9	14
4	70	1282	20.9	2.23	1546	410	−11	9

engines; this is equivalent to 28,800 cfm by displacement only, with no corrections. The carbon balance method of calculating the wind showed that the actual wind reaching the furnace was 22,300 cfm in Period One. The difference is large, but understandable, since piston engines are subject to wear, and their efficiency is dependent on mechanical condition at the time the test was made. During the first period, the furnace ran smoothly and uneventfully, so these first 10 days were considered a reasonable base period on an ore burden. The pressure drop from bustle pipe to top, averaged 9.1 psi. After two transition days with 30 pct pellets, there was no change in pressure drop; so, no attempt was made to increase the blowing rate. By the end of the period the pressure was 0.3 to 0.5 psi lower, but it should be noted that the actual wind by carbon balance calculated 1000 cfm less for the period.

During the transition to 50 pct pellets, the pressure drop remained slightly less; so, the blowing rate was raised to 80 rpm, corresponding to 30,400 cfm displacement. The average pressure drop for this period was 8.8 psi, and the calculated wind 22,200 cfm, indicating no increase even though the rpm of the engines was greater. The coke rate and $CO:CO_2$ ratio did not change much, and this was construed to mean that the blowing rate was about as high as it should be for No. 1 furnace using 50 pct pellets. Since the furnace had run smoothly during this period, it was decided to go to 70 pct pellets but not to increase the blowing rate. During the transition period, no difficulties were noted. However, immediately after this, the pressure drop began to increase, and by the end of the period was 2 to 3 psi greater, averaging 11.5 psi for the 10 days. This is a sufficiently-large increase to indicate significantly more resistance in the stock column, and the average calculated wind was down to 20,900 cfm.

There had been no delays during the first three periods other than casting delays which averaged 13, 10, and 9 min per day respectively. Mechanical delays developed during Period Four and averaged 41 min per day. Casting delays amounted to 16 min per day, making a total delay of 57 min per day. Four tuyeres were lost; there were some coke messes and troubles maintaining the iron notch. These difficulties unquestionably affected performance during the 70 pct pellet period, but the increase in pressure was clearly on the way before the burned tuyeres and coke messes began to appear. The $CO:CO_2$ ratio increased for the 70-pct pellet period. This increase would be expected to coincide with the higher pressure drop which would come about from less uniform gas distribution in the furnace. After observing the operations during this test, the conclusion was clear that the physical quality of pellets should be better. A fully satisfactory pellet must resist abrasion so as to minimize the accumulation of fines, which lead to gas channeling in the furnace, poor gas-solid contact, and higher $CO:CO_2$ ratios in the top gas.

Ashland test—1951

Since difficulties appeared to be associated with physical weakness of pellets in the 1950 test, it was agreed that a second test with stronger pellets was needed. It had been observed that, under the conditions of manufacture at the Ashland pelletizing plant, the more magnetic pellets were the stronger. It was decided to select a supply of pellets by magnetic separation and run another test on No. 1 blast furnace. The pellets thus selected were 4.3 pct −28 mesh when sampled at the blast furnace, while the pellets used in 1950 were 14.9 pct −28 mesh when sampled similarly.

The No. 1 furnace was run for 10 days without pellets as a base period for comparison purposes; it was the same burden used in 1950 for a similar base

Table III. Operating Data—1951 Ashland Test

Burden No.	Pellets, pct	Blast Temp, °F	Blowing Rate, cfm x 10^3	CO/CO_2	Dry Coke, lb/NTPI	Prod, tpd	Change from 1, pct	
							Coke	Prod
1	0	1222	23.7	2.15	1786	379	Base	Base
2	50	1148	23.8	1.83	1520	457	−15	21
3	70	1138	23.3	2.09	1540	484	−14	28

Table IV. Operating Data—1954 Middletown Test

Burden No.	Pellets, pct	Blast Temp, °F	Blow Rate, cfm	CO/CO_2	Dry Coke, lb/NTPI	Prod, tpd	Change from 1, pct	
							Coke	Prod
1	0	1156	80.3	2.16	1668	1357	Base	Base
2	33.4	1100	78.3	2.13	1550	1415	−7	4
3	50.3	1086	80.4	2.09	1505	1530	−10	13
4	67.8	995	77.4	2.06	1451	1505	−13	11

Table V. Effect of Pellets on Dust Production

Burden No.	Ashland				Middletown	
	1950		1951		1954	
	Pellets, pct	Dust + Sludge, lb/NTPI	Pellets, pct	Dust + Sludge, lb/NTPI	Pellets, pct	Dust + Sludge, lb/NTPI
1	0	62	0	73	0	207
2	30	63	50	46	33.4	320
3	50	63	70	61	50.3	439
4	70	73	—	—	67.8	554

period. The 30-pct pellet period was omitted due to confidence that had been gained in operating with pellets. Burdens two and three ran for 20 days each. The operating results are shown in Table III. The furnace took more wind in this test than it did in 1950. In addition, coke rate fell somewhat more and the production rate increased considerably. This happened in spite of the iron in the burden being somewhat lower in this test.

General observations indicated that this improvement was due to the better physical quality of the pellets. Strong support for this belief was obtained by correlating the effect of blowing rate and percentage of pellets on yield and pressure drop through the furnace. The top half of Fig. 1 illustrates that, if the percentage of pellets is held constant on the average, the yield decreased with increasing wind, as expected. Similarly, the lower half of Fig. 1 shows that, if the wind is held constant, the yield increased as more pellets were used. The top half of Fig. 2 illustrates that, when the percentage of pellets is constant, the pressure drop through the furnace increased as the blowing rate increased. The lower half of Fig. 2 shows that, if the blowing rate is held constant, the pressure drop decreased slightly as the stronger pellets were used; whereas, during the 1950 test, it increased significantly.

The furnace operated smoothly all through the test, and the results made everyone concerned feel that important progress had been made in producing satisfactory pellets. Although there was still room for improvement in strength and size control, there was no longer any doubt that pellets could be used in large-scale blast furnace operations, if pellets with the same level of physical quality could be maintained or improved.

Middletown test—1954

The first pellets made at Babbitt, Minn., were produced in shaft furnaces and went to Republic Steel Corp. at Chicago. Events at Babbitt led to the use of horizontal traveling grate pelletizing equipment, instead of shaft furnaces. These pellets were accumulated, and a test was run on the Middletown 28-ft furnace in the summer of 1954. The operating results are shown in Table IV.

For each percentage increase of pellets in the burden during this test, iron production increased 3.1 tpd, and the coke rate decreased 3.0 lb per NTPI. But these results were not as good as expected. The pellets, as charged to the furnace, contained 22.0 pct −28 mesh fines. The flue dust was very high, and the yield decreased 0.13 pct for each 1 pct of pellets added to the burden. Dust losses were so large that it was felt useless to attempt to increase the wind rate. Although the furnace operated at only 4.5 psi top pressure, the bleeders were cut badly and unaccounted losses were quite high. Table V compares dust losses on the two Ashland tests and the Middletown test. The cubic feet of air per minute per square foot of cross section was less on the Middletown furnace than on the Ashland furnace; so, these extremely high dust losses during the Middletown test must have been due to the high percentage of fines present. This experience served to emphasize again, the conclusions that were made after each of the earlier blast furnace tests, namely that great consideration must be given to producing strong pellets with very small percentages of flue dust sizes. If this is not accomplished, operations cannot possibly be as good as was originally expected.

Test with screened pellets

Pellets became more plentiful in 1956 and 1957. Quality had improved some in respect to fines, but samples from the ore yard still averaged about 15 pct −28 mesh instead of 22 pct found in the 1954 test.

It was decided to set up a screening station and screen enough pellets to make a short blast furnace test of a few days. The extreme fines tended to adhere to the rough surface of pellets because of moisture; thus, a good clean screening was impossible. However, the average quality of −28 mesh was lowered from 15.4 to 6.2 pct. After handling up to the stock house, samples from the bins averaged 10.4 pct −28 mesh, showing that additional fines must have been rubbed off the pellet surfaces. These pellets were used on the Middletown furnace in

Table VI. Operating Data—1957 Screened Pellet Test

Period	Days	Blast Temp, °F	Blowing Rate, cfm x 10^3		CO/CO_2	Dry Coke, lb/NTPI	Prod, tpd	Flue Dust + Sludge, lb/NTPI
			Ordered	Calc				
1	6	1122	97.6	90.0	2.07	1396	1985	345
2	8	1082	105.2	97.0	2.03	1401	2092	434
Avg	14	1100	101.4	93.5	2.05	1399	2039	389

Table VII. Operating Results for Middletown Furnace—1954-1960 Annual Averages

Year	Pellets,[a] pct	−28 Mesh After Tumble, pct	Blowing Rate, cfm × 10^3	Flue Dust + Sludge, lb/NTPI	CO/CO_2 Ratio	Carbon at Tuyeres, lb	Carbon in Stack, lb	Scrap, lb/NTPI	Dry Coke, lb/NTPI	Production, tpd
1954	10.9	22.0	83.9	365	2.16	1239	145	30	1694	1360
1955	5.9	19.7	92.5	237	2.35	1381	135	10	1819	1396
1956	40.3	13.4	91.1	272	2.23	1121	143	183	1537	1641
1957	61.5	9.7	92.0	301	2.06	956	177	154	1401	1852
1958	77.0	8.5	83.4	144	1.59	871	187	15	1298	1951
1959	71.0	7.3	99.7	214	1.43	855	162	66	1257	2497
1960	77.7	5.9	92.5	196	1.25	795	156	155	1184	2500
Lowest $CO:CO_2$ month										
11-60	85	--	84.0	—	1.11	—	—	51	1147	2345
Months of Highest Production										
5-59	84	—	105.0	—	1.25	—	—	0	1229	2690
5-60	84	—	109.0	—	1.24	—	—	0	1238	2804

[a] Pct of total iron bearing material charged.

April 1957 and were sufficient to run 14 days. For six days the reported blowing rate was 97,600 cfm and for eight days 105,200 cfm. The burden consisted of 83.8 pct pellets, 14.2 pct open hearth slag, and 2.0 pct miscellaneous material. Operating data are shown in Table VI.

Although the screened pellets still contained 10.4 pct −28 mesh fines when charged, the furnace performance was much better than in 1954 when the pellets contained 22 pct −28 mesh. There were no furnace difficulties that could be attributed to the high percentage of pellets charged. The coke rate did not increase significantly at the higher blowing rate and was actually somewhat lower than during the test of 1954, which used lower blowing rates. The $CO:CO_2$ ratio did not increase either and a good increase in production was obtained. Although this was a short test, it pinpointed the fact that the important thing to do was to get rid of the −28 mesh material before charging pellets to the blast furnace.

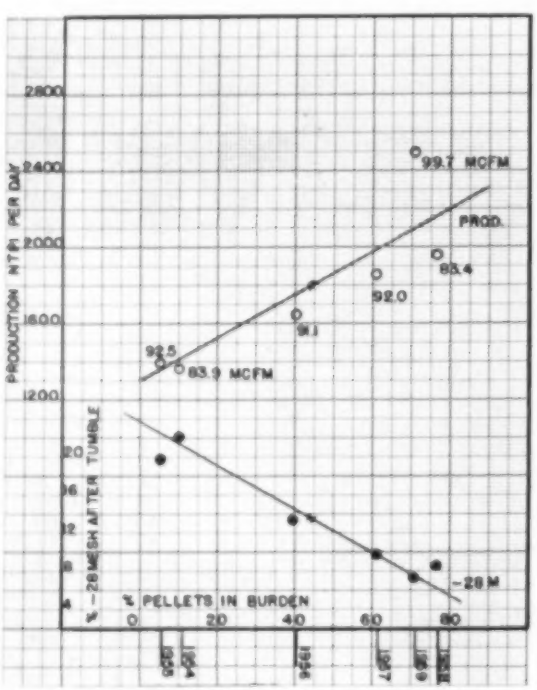


Fig. 3—Effect of pellets on production.

With the exception of the test on screened pellets in 1957, no detailed, specific blast furnace tests have been made by Armco since 1954. It was felt that the regular operating records would supply any information needed and reflect any changes in pellet quality. The efforts of the operating people at Silver Bay, Minn., were meeting with success, and the −28 mesh fines continued to decrease.

Table VII gives a summary of the production and coke rate of the Middletown furnace by years as the supply of pellets increased. As the fines in the pellets decrease, the flue dust stayed at a tolerable level even at high blowing rates. The $CO:CO_2$ ratio in the top gas steadily became lower as more pellets were used and did not increase at high blowing rates, indicating that from the chemical standpoint the furnace is a long way from being over-blown when using high percentages of good quality pellets. It is interesting to note that in 1955 and in 1960, the average blowing rate was the same—92, 500 cfm. The $CO:CO_2$ ratio averaged 2.35 in 1955 and 1.25 in 1960. Improvements in coke rate and production for 1960 over 1955 were 35 pct and 79 pct, respectively. These percentages are remarkably comparable to those on the Minneapolis experiment in 1948.

During the record month of May 1960, the furnace operated satisfactorily on blowing rates up to 114,-000 cfm and the average blowing rate for the month was 109,500 cfm. It seems reasonable to be optimistic and to expect that blowing rates can be further increased if the strength and abrasion resistance of pellets is maintained.

Some data from Table VII are shown in Figs. 3 to 5. Fig. 3 shows how production has increased on the Middletown furnace as more pellets became available. The points plotted are annual averages. The slope of the production line is approx 11 tpd per 1 pct pellets in the burden. The average annual blowing rate is shown with each point. A large part of the increase in production is due to the increased blowing rates that have been possible with pellets and not to their chemical analysis. However, it must be noted that the higher iron:silica ratio in pellets relative to ores previously used does contribute its part in obtaining lower coke rates, thus requiring less air to make a ton of iron. Due to the excellent chemical uniformity of pellets, it is seldom necessary to make a burden change, and iron and slag chem-

istry are easily controlled. Also, freedom from frequent burden adjustments permits giving more attention to mechanical operation and encourages higher driving rates. The line in the lower half of Fig. 3 shows how the quality of pellets has improved over the years as measured by the percentages of −28 mesh fines after a tumble test.

Fig. 4 shows some other effects of using pellets. The total coke rate and the carbon used at the tuyeres have steadily decreased. The $CO:CO_2$ ratio has come down as the total carbon requirements decreased and has been as low as 1.24 for specific months, as noted in Table VII. The carbon used in the furnace by reaction with carbon dioxide, has increased somewhat. This is indicative that the furnace needed more reducing gas after the carbon used at the tuyeres became less; therefore, a somewhat larger quantity of carbon reacted with sources of oxygen other than air.

Fundamentally, if more carbon is converted to gas by agencies other than air at the tuyeres, the $CO:CO_2$ ratio should increase, not decrease, but the opposite has been true. Some interesting comments on this can be collected from Fig. 5. Fig. 5A shows that the carbon gassified in the stack has been higher when the carbon gassified at the tuyeres has been lower. Fig. 5B shows that, in spite of this, the $CO:CO_2$ ratio has been lower when the carbon gassified at the tuyeres has been lower. Fig. 5C depicts the fact that the $CO:CO_2$ ratio has been lower when the carbon used in the stack has been higher. This is consistent with 5A and 5B, but in disagreement with the fundamental statement above. If the data from 5B and 5C are adjusted by multiple correlation to find the independent effect of carbon in the stack on $CO:CO_2$ ratio, with carbon at the tuyeres held constant, the slope of the line reverses itself as shown in Fig. 5D. This is now in agreement with the fundamental relation expressed before. It thus becomes clear that, in looking at raw data, the observed change in $CO:CO_2$ ratio is a combined effect of carbon used at the tuyeres and carbon used in the stack and these two variables effect it in opposite ways. With pellets, the decrease in carbon at the tuyeres has been enough to lower the $CO:CO_2$ ratio even though carbon used in the stack has increased. These relations also point out how reducing power is lost as the thermal demands require less carbon at the tuyeres. This supports the belief that further decreases in coke rate can be obtained by supplying supplemental reducing power in the form of natural gas.

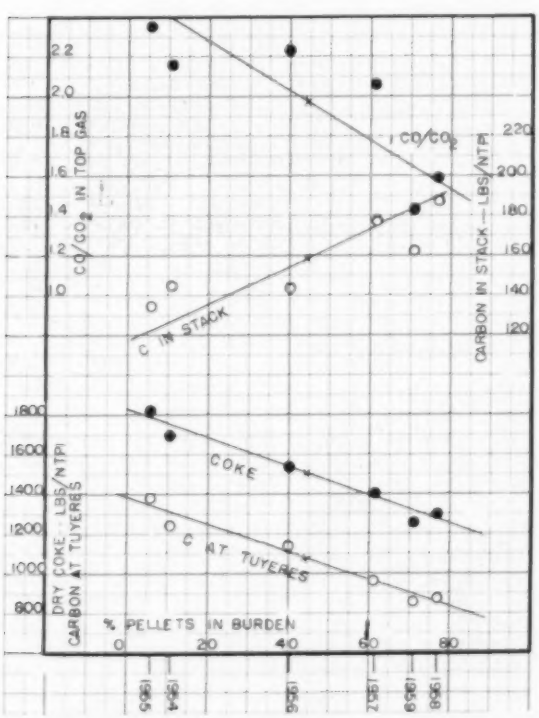


Fig. 4—Effects of using pellets on $CO:CO_2$ ratio, carbon in the stack, coke rate, and carbon at the tuyeres.

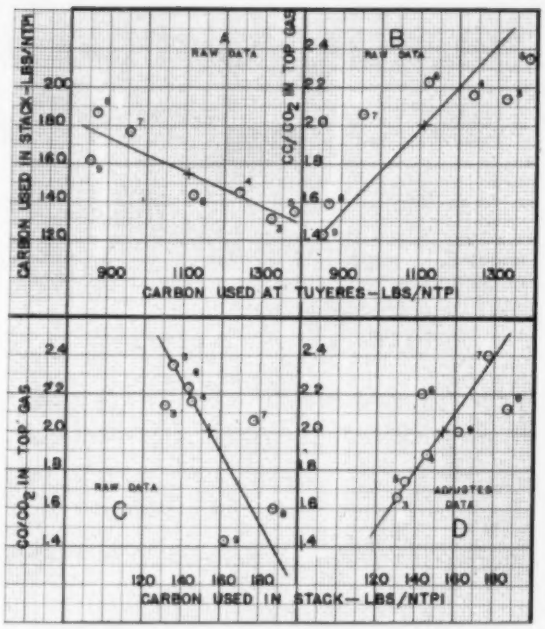


Fig. 5—Relation of carbon at tuyeres to carbon in the stack and CO/CO_2 in the top gas.

Conclusions

Substitution of taconite pellets for ores has resulted in lower coke rates and increased production. These improvements are due to uniform chemical analysis and better physical quality of the material. Experience indicates that physical quality and freedom from fines should be further emphasized because blowing rates can be increased to a great extent without loss of efficiency. Good physical quality will also facilitate high blast temperatures and the use of new injection techniques for gas and other hydrocarbons, with or without oxygen. If blowing rates are increased sufficiently, oxygen enrichment may develop more slowly unless it can be shown that cost savings can be attained by utilizing oxygen.

Although, great strides in blast furnace technology have been made in the last decade, the limit in improvement has not yet been reached. Physical quality of raw materials will continue to assume more importance because upon it depends the successful application of other techniques for improving operations.

PRE-REDUCED IRON-ORE PELLETS, Their Experimental Preparation

A super blast-furnace feed—hard pre-reduced pellets—has been the objective of small-scale experimental work by the US Bureau of Mines. Results have been sufficiently promising to continue research to develop a continuous production method.

by J. P. Hansen, N. B. Melcher, and M. M. Fine

The US Bureau of Mines is investigating the possibility of simultaneous induration and partial reduction of green iron-ore pellets to prepare a super blast-furnace feed. The objective is not only to produce a reduced pellet, but one physically competent to withstand the rigors of blast-furnace smelting. This contrasts with the many direct-iron processes, since it is primarily one of pellet hardening, and complete metallization would not be accomplished. The metallization would be limited to that which could be readily achieved during pellet induration.

Previous experiments with a small kiln at Laramie, Wyoming,[1] showed that 80 pct metallization of green pellets could be attained during induration without excessive fuel or residence time. The metallic iron in the reduced pellets forms bonds at a lower temperature than hematite, which permits induration at temperatures lower than the 1300 to 1400°C usually required for iron-oxide pellet hardening. The additional fuel requirements for the reduction could be more than offset by lower coke rates and higher production from the blast furnace. In addition, a less expensive fuel would be utilized for some of the reduction which normally occurs in the blast furnace.

Calculations based on experience at the Bureau's experimental blast furnace[2] indicate that 80-pct metallization of the pellets prior to charging will result in a 13-pct saving in coke with a 10-pct increase in production, even if no further reduction of the ore is accomplished in the stack of the blast furnace. If the charge were reduced to 85-pct metal in the stack, the coke rate would drop 17-pct concurrent with a 14-pct increase in production. Further reduction in the stack would effect even greater coke savings and production increases by diminishing the coke gasified by the solution loss and by saving the heat lost by this endothermic reaction.

Experiments

Laboratory experiments were performed at the Minneapolis Metallurgy Research Center to determine the time and temperature required to attain 80-pct metallization of green iron-ore pellets using various solid reductants. Pellets (approx ½-in. diam) were prepared from a 50-50 mixture of Michigan spiral and flotation concentrate containing 63-pct Fe and 5.6-pct SiO_2 which was pulverized to 96-pct −100 mesh. The mixture contained hematite and magnetite; approximately one-third of the iron was magnetite. Pellets were formed in a drum pelletizer, using 24 lb of bentonite and 1.5 lb of soda ash per ton of feed, and dried at 105°C. Sixty-gram batches of dry pellets were mixed with the solid reductant in fireclay crucibles and covered with an additional layer of reductant using about 180g of reductant. The crucibles were covered with a small inverted scorifying dish, which was sealed in place with asbestos mud. A small hole had been drilled in the scorifying dish to prevent the buildup of excess pressure inside the crucible. Four sealed crucibles were charged to a muffle furnace operating at the desired temperature, and one was withdrawn every half hour. After air-cooling to room temperature, the crucibles were opened, and the pellets separated from the excess reductant.

The crushing strength of the pellets was determined using a dual-scale hydraulic jack. The degree of metallization (metallic iron/total iron) was determined from chemical analysis. Metallization and crushing strength achieved with lignite, lignite char, anthracite fines, coke breeze, and petroleum coke were determined at 950°, 1050°, 1150°, and 1250°C.

Results

The metallization and crushing strengths resulting from the use of petroleum coke are presented in Fig. 1A. As shown, the pellets were relatively unaffected at 950°C; however, at 1050°C, both metallization and crushing strength were considerably improved. The decrease in crushing strength between 90 and 120 min at 1250°C was due to the formation of a plastic iron shell; so, under a compressive load the pellets would flatten and eventually rupture without a sharp breaking point. This phenomenon was usually observed in the highly metallized pellets treated at 1250°C.

The metallization and crushing strength for pellets indurated with anthracite fines and coke breeze are shown in Figs. 1B and 1C respectively. These fuels reacted similarly in that reduction was quite rapid (as compared with petroleum coke) and was accelerated by higher temperature. Metallization reached a plateau after which reduction was slow; the magnitude of this plateau depends mostly on the reductant. With coke breeze and anthracite this plateau was between 80 and 90 pct and was relatively unchanged with longer times or higher temperatures. Up to 1150°C, crushing strength and metallization

J. P. HANSEN, N. B. MELCHER, and M. M. FINE are with the Minneapolis Metallurgy Research Center of the US Bureau of Mines.

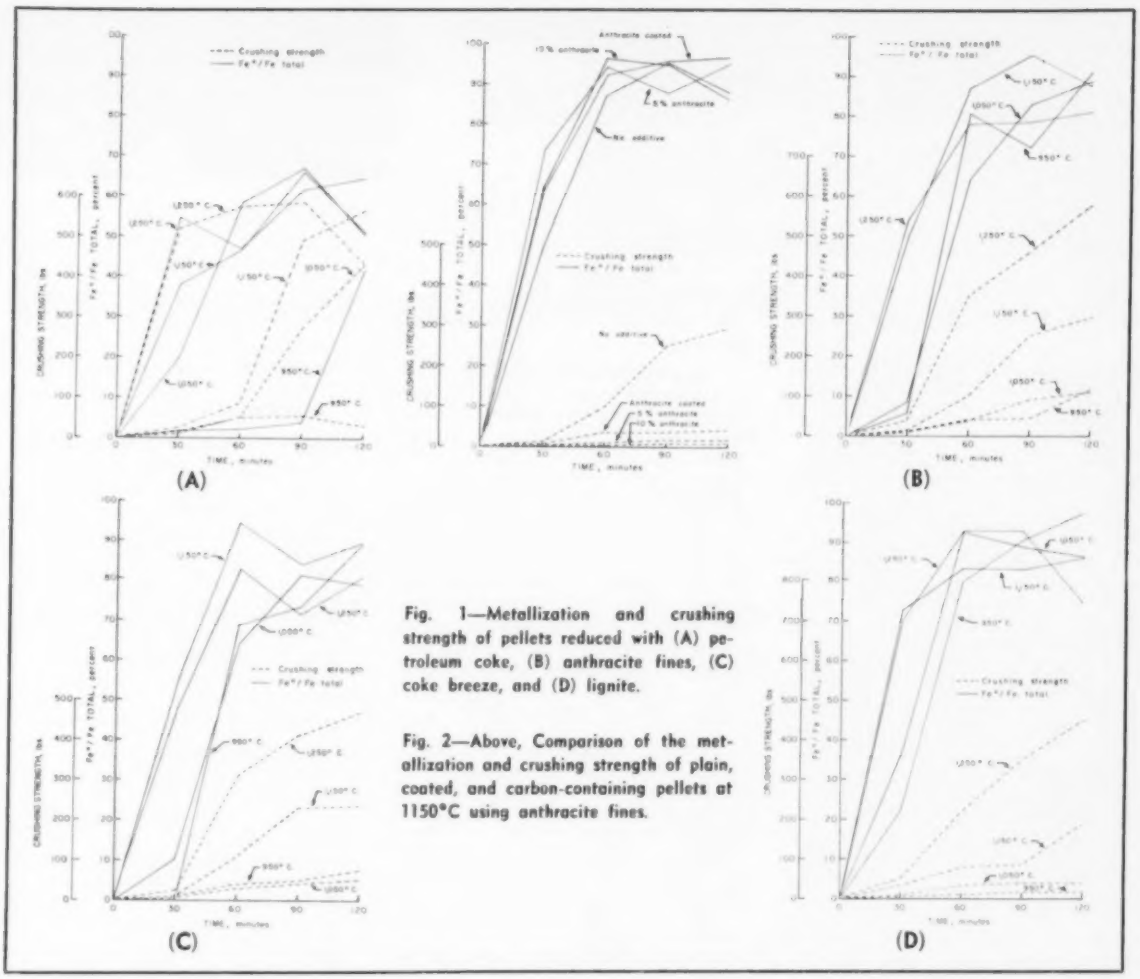


Fig. 1—Metallization and crushing strength of pellets reduced with (A) petroleum coke, (B) anthracite fines, (C) coke breeze, and (D) lignite.

Fig. 2—Above, Comparison of the metallization and crushing strength of plain, coated, and carbon-containing pellets at 1150°C using anthracite fines.

increase rapidly with higher temperatures; however, above that point, very little increase in reduction occurs, but a sharp increase in crushing strength is realized.

The pellets reduced rapidly even at 950°C, with lignite as shown in Fig. 1D. Results were substantially the same using lignite char. Metallization was higher with lignite and lignite char than was attained using any other reductant, and the reaction rapidly went to nearly 100-pct metal. The pellets, however, did not have adequate crushing strength at temperatures below 1150°C.

The effects of coating the pellets with anthracite fines during pelletizing and including the fines in the pellet are shown in Fig. 2. The more intimate association between the ore and reductant generally increased the metallization, but the pellet strength was reduced sharply.

Limestone was added to the feed in an attempt to produce a self-fluxing pellet. However, this addition resulted in a weak, porous pellet with an increased sulfur content.

The crushing strength of several commercially-produced iron-ore pellets was determined in order to obtain some criterion for strength requirements. The results indicate wide variations in pellet strength, with the majority being below 350 lb. However, it is evident from the data of figures 1B, C and D that the highly metallized laboratory pellets were superior to most of the commercial iron-oxide spheres.

Results of these laboratory experiments show that it should be feasible to reduce green pellets to 80-pct metallic iron with any of the fuels tested except, possibly, petroleum coke. The data now available suggest that an operating temperature range between 1150° and 1300°C will be required to produce pellets with acceptable crushing strengths. The ability of the pellets to undergo plastic deformation when subjected to high pressures give them superior crushing strength, and probably good impact strength. When the pellets are highly stressed by compressive loading, yielding will frequently protect them from total destruction and reduce degradation of the pellets during handling and in the furnace.

The Minneapolis Metallurgy Research Center considers the results of these small-scale experiments sufficiently promising to continue research to develop a continuous method to produce hard, prereduced pellets. Ultimately, enough pellets will be produced for research in the Bureau's experimental blast furnace at Bruceton, Pa.

References

[1] T. L. Johnston and W. M. Mahan: Laramie Sponge-Iron Pilot Plant, Bureau of Mines Report of Investigations no. 4376, Sept. 1943.

[2] N. B. Melcher: Iron, Steel, and Ferroalloys Investigated at Bruceton, JOURNALS OF METALS, vol. 12, no. 5, May 1960, pp. 406-409.

The Columbium Supply

by Chester T. Sims of General Electric Co.

Columbium is rapidly becoming the best-known refractory metal. Its reputation is well founded, for government, universities, and a large number of major companies in basic industries are active in its technology. Their interest is based on high confidence in its versatile future—in jet and rocket engines, in nuclear reactors, in space vehicle structures, and in a variety of less-glamorous uses.

Most refractory metals are fairly scarce. This causes potential users to hesitate before moving into refractory metals for any massive application. Scarcity also guarantees a high price picture. Until recently, columbium was no exception. However, new data show columbium can step out of the traditionally *rare* role of most refractory metals, and will be positively available in quantity.

NATURAL OCCURRENCE

Reactive and refractory metals of interest for space and nuclear applications have the following relative abundance in the earth's crust, using zirconium as a basis, and including nickel for comparison:

Relative Availability of Reactive and Refractory Metals

	Information Source			
	Mason	Urey	Goldschmidt	Calculated from MAB Report
Zr	100	100	100	100
Cr	91	59	81	—
Ni	36	28	33	—
W	31	9	10	—
Cb	11	0.5	8	30
Mo	3	4	7	3
Hf	2	1	1	—
Ta	1	0.2	0.3	3

Depending upon the information source, columbium is 0.5 to 30 pct as available as zirconium. Urey, himself, who originated the lowest abundancy estimates for columbium, throws doubt on his own data. Goldschmidt's data has been the standard until now. However, the MAB report is based on extensive new ore findings, making it the most reliable document available. For the present, it seems conservative and proper to consider the abundance of columbium in the earth's crust to be 30 pct of zirconium, which is about the same as nickel.

RESERVES

Several estimates of actual free-world columbium ore reserves have been compiled recently. Of these, the most recent and authoritative appears to be the two Materials Advisory Board reports, *Summary Report of the Committee on Refractory Metals* and a second volume, *Report of the Committee on Refractory Metals*. Representatives of leading US industrial companies, research organizations, and universities contributed to provide these consensus reports on various aspects of refractory metals technology. The *Summary Report* makes several facts clear about reserves, as follows:

1) The metal content of known mineral resources of non-communist countries "provides a total of 7 million tons of columbium metal contained in such reserves." This is more than Mo, V, W, and Ta combined, and only Cr and Zr are more plentiful;

2) The 7-million short tons of presently-known ore reserves is equivalent to 4 million tons of mill products;

3) The "known deposits of columbite- and pyrochlore-containing ores have not been completely explored, and the probable potential may be much greater"; and

4) Major reserves are in Nigeria, Brazil, Canada, Uganda, Tanganyika, Kenya, Norway, and the United States. "The Brazilian deposits of columbium in the form of pyrochlore are the world's greatest known resources."

In addition to this information, the more detailed MAB report which includes a large section entitled, *The Panel Report on Columbium and Tantalum*, makes other facts clear. This report states that the estimated South American ore reserves of Wah Chang Corp., a leading US producer, are approx 4 million tons of contained columbium. Work to prove these reserves is progressing, and the numbers given are now believed to be conservative. Another South American source may have about 5 million ton reserves. Continental US has about 100,000 short tons of proven reserves held by duPont, and Canada 500,000 tons, held by a variety of mining companies.

The Western Hemisphere sources, obviously of importance to the US for strategic reasons, are about four times richer in columbium than the rest of the world combined.

SEPARATION OF PYROCHLORES

The majority of the Western Hemisphere ores are of the pyrochlore-type, from which it is more difficult to separate columbium than the traditional columbites, usually imported from Africa. However, several US and Canadian companies now have commercially-feasible separation processes, although at the present time these processes are presumed to be expensive compared to separation from columbite. Ultimately, they will be competitive.

PRICE AND PRODUCTION

A relatively large number of US companies are marketing, or are active in some other commercial aspect of columbium metal.

Delivery of experimental quantities to consumers has been excellent for the last two to three years. The leading companies are confident in their ability to supply potential engine, airframe, space, and nuclear power plant needs.

In 1956, the price of *high purity* sheet was about $100 to 125 per lb. The principal US producer was Fansteel, utilizing powder metallurgy processing. Now, arc-melting and electron-beam melting processes have been introduced and have a heavy share of the market. Bar and sheet, of improved quality over the 1956 product, cost in the neighborhood of $35 per lb, down from $65 per lb less than 18 months ago.

The MAB Summary Report estimates 1000 tons per year production is attainable in two years, and 10,000 tons per year attainable in two to five years, providing pyrochlore ores are expolited more completely, controlled-atmosphere rolling mills are developed, and alloy sheet rolling improves. At maturity of the industry (10,000 tons per year), a price of $5 per lb is predicted. This means that columbium will be down to the price level of zirconium and molybdenum ($10 to $20 per lb) in a very few years. Columbium is fabricated with less difficulty than zirconium and less scrap loss occurs; so, a maturity price considerably less than for zirconium and near titanium does, indeed, seem feasible.

AIME STAFF:

SECRETARY—ERNEST KIRKENDALL

ASST. SECRETARIES—J. B. ALFORD, H. N. APPLETON, J. C. FOX, R. W. SHEARMAN, C. J. HICKS

ASST. TREASURER—JOHN LYNCH

METALLURGICAL SOCIETY STAFF:

SECRETARY—R. W. SHEARMAN

ASST. SECRETARY—D. C. JOHNSTON

NEWS OF YOUR PROFESSION

Extractive Metallurgy Session at Southwest Minerals Industry Conf.

An Extractive Metallurgy Session will be one of the features of the Southwest Minerals Industry Conference which will be held at the Stardust Hotel in Las Vegas, Nev., April 24-25. This session, which will be held on Monday, April 24, will offer a discussion on *Steel Manufacture in the Pacific Southwest—The Market and Raw Material Potentials* by Walter H. Vaskuil of the University of Nevada. Other papers will include *Alumina From San Gabriel Anorthosite* by R. V. Lundquist of the US Bureau of Mines, and a discussion of the *Atlantic City Project* by S. H. Cohlmeyer, R. C. Morgan, and A. S. Henderson of U.S. Steel Corp.

Preceding the Extractive Metallurgy Session will be an All Participants Luncheon which will be held at noon in the Cafe Continental. The welcoming address will be delivered by Grant Sawyer, Governor of Nevada. A second All Participants Luncheon will be held on Tuesday, April 25 in the International Room of the Stardust. The speaker will be R. R. McNaughton, President of AIME.

Physical Metallurgy will be the title of a session to be held on Tuesday in the Board of Governor's Room. A paper on *Properties of Electron Beam Melted Metals and Alloys* will be presented by C. d'A. Hunt, Temescal Metallurgical Corp. Leo J. Barron of E. I. DuPont de Nemours & Co. Inc., will discuss *Commercial Applications of Titanium Metal.* Russell Hardy, Joseph L. Gunter, and Thomas A. Hamm of Oregon Metallurgical Corp., will present a paper on *Casting Tungsten Base Alloys.* The session will conclude with a paper on *Improved Austenitic Manganese Steels for Abrasion Resistant Applications* by T. E. Norman, Climax Molybdenum Co.

Vacuum Technology Congress Scheduled October 16-19

The Second International Congress for Vacuum Science & Technology will be held at the Shoreham Park Hotel in Washington, D. C., October 16-19. The congress will provide a forum for the discussion of the latest developments in vacuum science and technology.

Abstracts from the US and Canada should be air-mailed in triplicate to L. E. Preuss, program chairman, Dept. of Physics, Edsel B. Ford Institute for Medical Research, Henry Ford Hospital, Detroit 2, Mich. Abstracts originating in other countries must be airmailed in duplicate to either the National Vacuum Society or the International Organization for Vacuum Science and Technology.

July 20 is the deadline for submission of manuscripts. They should be submitted in triplicate, directly to the program chairman.

Tentative acceptance of papers will be announced shortly after April 1. Abstracts and manuscripts may be typed and read in French, English, or German. Authors must notify the Program Chairman of the language of the oral presentation. Final acceptance of papers will be based on the completed manuscript.

1961 Directory of Members

A Directory of members of The Metallurgical Society will be published this summer. Cards have been sent to all members to learn their present addresses and primary divisional affiliation. In addition, to advise advertisers as to the readership of JOURNAL OF METALS, information on occupations and industry classifications is also requested. These data will *not* appear in the Directory.

Full information about how to order the Directory will be given in the May issue.

K. L. FETTERS

K. L. Fetters Is Named Metallurgical Society President-Elect

Karl L. Fetters has been named Vice President and President-Elect of The Metallurgical Society for 1961. Dr. Fetters is vice president of research and development, The Youngstown Sheet and Tube Co. He was the 1958 Chairman of the Iron and Steel Division.

A member of AIME since 1937, Dr. Fetters was a metallurgical assistant with the National Tube Co. from 1933 to 1936 and open-hearth metallurgist, Youngstown Sheet and Tube Co., 1936-38. Next he received his Ph.D. from the Massachusetts Institute of Technology in 1940. He went back to Youngstown Sheet and Tube for one year; this was followed by a two-year term as assistant professor of metallurgy at Carnegie Institute of Technology. He rejoined Youngstown in 1943 and has continued the association. Among the awards he has received is the American Iron and Steel Institute's Medal (1948) for co-authoring a paper on *The Mineralogy of Basic Open Hearth Slags.*

METALLURGICAL SOCIETY DIRECTORS

IMD

* Year of expiration of term.

John H. Hollomon

Dr. Hollomon ('62)* is general manager of General Electric's General Engineering Laboratories, Schenectady, N. Y. Dr. Hollomon, who received his Ph.D. from Massachusetts Institute of Technology in 1946, has been a member of AIME since 1944. He is a Fellow of the American Academy of Arts and Sciences, and in 1954 was chosen one of the country's 10 leading young scientists in industry by the US National Junior Chamber of Commerce. Dr. Hollomon has been a member of The Metallurgical Society's Committee on the Metallurgical Profession and the Publications Committee.

John H. Scaff

Mr. Scaff ('63)* has been on the research staff of Bell Telephone Laboratories for more than 30 years. He has been responsible for research and development in the fields of magnetic materials, semiconductors, and other communication materials responsive to metallurgical control. He has been awarded a number of patents relating to semiconductor technology.

Mr. Scaff has been chairman of the Program and Membership committees, and a member of the IMD Executive Committee. He has been chairman of IMD and a director of AIME. In 1955, he was chairman of the Metals Branch Council, forerunner of The Metallurgical Society.

William J. Harris, Jr.

Dr. Harris ('64)* is executive director of the Materials Advisory Board, National Academy of Sciences-National Research Council, (NAS-NRC). He served previously as a Director in 1957-58, and filled the unexpired term which was created when J. S. Smart, Jr., became Vice President of The Metallurgical Society. He was chairman of IMD in 1958. He has served on various committees of AIME, IMD, and The Metallurgical Society.

Dr. Harris received his Sc.D. from Massachusetts Institute of Technology in 1947. He joined NAS-NRC in 1957 after serving as assistant to the director, Battelle Memorial Institute.

ISD

Ralph W. Farley

Mr. Farley ('62)* has been with Republic Steel Corp. since 1935. He is now director of process development for the Chicago district. He has served on the ISD Electric Furnace Conference Committee and the Physical Chemistry of Steelmaking Committee. Mr. Farley received his B.S. in chemical engineering from the University of Michigan in 1932, and worked as a plating foreman and consultant with the Diamond Silver Co., before joining Republic. A member of AIME since 1946, Mr. Farley is also a member of ASM and API.

Michael Tenenbaum

Dr. Tenenbaum ('63)* is filling the unexpired term of Dr. Karl L. Fetters who has become Vice-President and President-Elect of The Metallurgical Society. Dr. Tenenbaum received his Ph.D. in metallurgy from the University of Minnesota in 1941. Following his graduate work, he returned to Inland Steel Co., where he had been employed in 1936. He is now assistant general manager of technical services. Dr. Tenenbaum joined AIME in 1939, and has held numerous positions in ISD, and in the Chicago section, AIME. He has twice been awarded the *National Open Hearth Committee Award.*

Harold B. Emerick

Mr. Emerick ('64)* is director of technical services for Jones & Laughlin Steel Corp. He joined the company as a metallurgical investigator in 1935 while still attending Carnegie Institute of Technology. He was chairman of ISD in 1957. In 1942, Mr. Emerick was co-author of the paper on open-hearth practice which won the *F. B. McKune Memorial Award.* He is also the author of *Basic Open Hearth Steelmaking,* which was published by AIME in 1951. He is a member of the American Society for Metals and the American Iron and Steel Institute.

EMD

John D. Sullivan

Mr. Sullivan ('62)* is technical director of Battelle Memorial Institute. He was the first chairman of the Extractive Metallurgy Division (1948-50) and one of its founders. Mr. Sullivan has been active in AIME since joining the Institute in 1930. He is a former chairman of the Douglas Award Committee, and has been a member of EMD's Executive Committee and Publications Committee. He has also served on the IMD Executive Committee. Mr. Sullivan is the author of more than 100 papers on metallurgy, chemistry, and ceramics.

A. W. Schlechten

Dr. Schlechten ('63)* is professor of metallurgical engineering and chairman of the department, Missouri School of Mines and Metallurgy, a position he has held since 1946. He received his Ph.D. from the Massachusetts Institute of Technology in 1940.

He has been active in Institute activities since joining in 1934. A past chairman of EMD and the St. Louis section, AIME, he is a past and present member of many AIME, Metallurgical Society, and EMD committees.

Albert E. Lee, Jr.

Mr. Lee ('64)* is technical director, Amco div., American Metal Climax, Inc. He graduated from Lehigh University in 1941 and served as procurement officer in the US Army's 1941 until 1946, joining AMC in 1946. Philadelphia Ordnance District from He transferred to the New York office from the Blackwell, Okla., zinc smelter in 1955.

During 1958, Mr. Lee was a member of The Metallurgical Society Publications Committee and the JOURNAL OF METALS Advisory Subcommittee, and the EMD Papers and Programs Committee.

(Biographies and pictures of the Society President and Division Chairmen appeared in the February issue.)

Nondestructive Testing Convention Planned May 17-19 in Montreal

The Society for Nondestructive Testing will hold its first Eastern Regional Convention at the Sheraton-Mount Royal Hotel in Montreal, Que., Canada, May 17-19, 1961.

The convention will consist of 24 technical papers presented at eight sessions by authorities in the field of nondestructive testing. In addition, on the final day, an Educational Session will be held covering many aspects of inspection, such as *radiography — ultrasonics — magnetic practice and dye penetrant testing methods.*

An extensive ladies program has been arranged for the wives of visitors to the convention. This includes a luncheon, sightseeing tours, a shopping tour, and other activities.

Inquiries should be sent to Maurice Daly, Publicity Chairman, 2168 Addington Street, Montreal 28, Que., Canada.

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Fall Meeting Scheduled By French Metals Group In Paris Oct. 17-21

The Fall Metallurgical Meeting, sponsored by the Société Francaise de Métallurgie, will be held in Paris at the Maison de la Chimie, October 17-21, 1961.

The topic of the meeting will be *Metal Forming.* It will cover the metallurgical processes involved in deformation at hot and room temperature, as well as the preliminary stages of foundry and sintering work. Original papers concerning other metallurgical subjects may also be presented.

A French language pamphlet containing resumes of all papers to be presented at the meeting will be published by the Société Francaise de Métallurgie in September 1961, together with the program of the meetings.

The oral presentation of the papers at the Fall Metallurgical Meetings has to be in French. A complete text of the papers will be published in the Revue de Metallurgie.

For further information, write to the Secretary of the Société Francaise de Métallurgie, 25, rue de Clichy, Paris 9éme.

Froth Flotation's 50th Year Will Be Observed in Denver

Thirty papers emphasizing the new, the novel, and the theoretical on six phases of froth flotation will be presented at the Commemoration of the 50th Anniversary of Froth Flotation, which will be held in Denver, September 17-20. The papers will be presented in six single, non-overlapping sessions.

Headquarters for the meeting will be the Cosmopolitan Hotel and the Brown Palace Hotel. The meeting, sponsored by the Minerals Beneficiation Division of the Society of Mining Engineers of AIME, is open to anyone interested in minerals beneficiation. Registration fee for the conference is $15.00, which includes a bound volume of all papers which will be presented at the meeting. Registration for the meeting will be in the West Annex of the Brown Palace Hotel on Sunday, September 17.

Social activities planned for the meeting include a Registration Cocktail Party on Sunday, a Welcoming Luncheon on Monday, a cocktail party and dinner dance on Tuesday, and a Scotch Breakfast on Wednesday.

For further information write to *O. W. Walvoord, 301 Detroit St., Denver 6, Colorado.*

AROUND THE SECTIONS

Mardi Gras royalty at the Utah section's ball, held on February 4, are (l to r), Robert C. Meyer, Richard S. Stone, Milton Williams, king; Mrs. Phil Mudgett, queen; Mrs. E. V. Hanna, queen's attendant; and LeGrand Hunt, king's attendant.

Southeast section, AIME, held its first meeting of the year at the Thomas Jefferson Hotel in Birmingham on February 16. The speaker for the evening was Eugene K. Graham, assistant general superintendent of Fairfield steel works of the Tennessee Coal & Iron div., U. S. Steel Corp. Mr. Graham's speech traced the parallel growth of TCI and the South since Alabama's first commercial steel was made in 1899. He furnished an interesting insight into the manner in which scientific advancement, coupled with sound business practice, fosters economic growth and makes today's living more pleasant.

New officers for 1961 were installed at the meeting. Taking over as section chairman is J. W. Nicol, general superintendent of mines, U.S. Pipe & Foundry Co. Other officers installed were: M. M. Marchich, secretary-treasurer; L. S. Chabot, Jr., first vice chairman; and C. K. Donoho, second vice chairman.

Western section National Open Hearth Steel Committee met March 15 at the Rodger Young Auditorium in Los Angeles. Guest speaker was Tom Evans, superintendent of melting, National Supply div., Armco Steel Corp., who discussed *Fluid Mold Casting of Ingots*. The talk was preceded by a social hour and dinner.

Utah section held a Mardi Gras Ball February 4 at the Prudential Federal Savings auditorium in Salt Lake City. It was the fifth annual miners review, consisting of a social hour, dinner, queen contest, Krewes parade and dance.

King Rex of the ball was Milton Williams. He and his attendant, LeGrand Hunt, wore authentic costumes from New Orleans. Mrs. Phil Mudgett was chosen queen of the ball, and Mrs. E. V. Hanna was her attendant. Six Krewes (groups) paraded through the hall and presented sketches.

Institute History Prepared by Robie

A 48 page *History of the Institute —II* has been prepared by Edward H. Robie, who served as Secretary of the Institute from 1949-55. The new publication covers the fifteen year history of AIME from 1947-1961. A previous volume, prepared by A. B. Parsons, covered the 75 year history of the Institute up to 1947. The new edition contains a list of the officers and directors of the Institute from 1948-61. Copies of the paper bound brochure are available for $1.00 each from AIME, 29 West 39 Street, New York 18, N. Y.

MEMBERSHIP

Proposed for Membership
Metallurgical Society of AIME

Total AIME members on January 31, 1961, was 35,022; in addition 1,926 Student Members were enrolled.

ADMISSIONS COMMITTEE

W. L. Brytczuk, Chairman; S. C. Carapella, Jr.; J. W. Hanley; T. D. Jones; H. C. Larson; Harold Margolin; Shadburn Marshall.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

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Bailey, Charles F., Middletown, Ohio
Bliss, Charles, Cambridge, Mass.
Blough, Richard C., Johnstown, Pa.
Campbell, George A., New York, N. Y.
Chyle, John J., Milwaukee, Wisc.
Fraser, John P., Houston, Tex.
Freeman, Robert R., New York, N. Y.
Herbert, Ivor C., London, England
Hunt, LeGrand A., Provo, Utah
Ikeno, Teruo, Hokkaido, Japan
Krynicki, Albin F., Sacramento, Calif.
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Neubauer, Edwin P., Ames, Iowa
Seman, Donald J., Munhill, Pa.
Shepard, Marion L., Wapping, Conn.
Waller, Jerry M., New Kensington, Pa.

REINSTATEMENT—CHANGE OF STATUS

Junior to Member

Mullin, Bertram M., Washington, D. C.

Associate to Member

Borik, Frank, Berkley, Mich.

Student to Member

Miller, John A., Kokomo, Ind.

Student to Junior

Agers, Donnel W., Kankakee, Ill.

Junior to Student

Altshuler, Thomas L., Oxford, England

REINSTATEMENT

Junior Member

Atkins, James W., Louisville, Ky.
Chander, Jagdish, Montreal, Que., Canada
Steel, John S. Jr., Newark, N. J.

RE-ELECTION

Associate Member

Smith, Frank A., Pittsburgh, Pa.

Member

Vignola, Paul R., Talcahuano, Chile

CHANGE OF STATUS

Junior to Member

France, Leonard L., Pittsburgh, Pa.

Associate to Member

Anderson, Herbert T., Lambertville, Mich.
Beliberg, Melvin L., Pittsburgh, Pa.
Cadoff, Irving B., Bronx, N. Y.
Chenkovich, Robert F., South San Francisco, Calif.
Fopiano, Paul J., Winchester, Mass.
Goldberg, Perry D., Reseda, Calif.
Gottstein, Jay S., Selby, Calif.
Heise, Robert E., Reseda, Calif.
Joynt, Stuart F. Jr., Buffalo, N. Y.
Kimura, Kiroshi, Tokyo, Japan
Krivsky, William A., Fremont, Ohio
Kurtz, Norbert R., Chicago, Ill.
Macdonald, A. J. III, Steubenville, Ohio
Teague, James E., Black Eagle, Mont.
Walter, John L., Scotia, N. Y.
Weiner, Lazarus C., Great Neck, N. Y.

AN ABSTRACT OF THE ANNUAL REPORT OF THE SECRETARY, THE METALLURGICAL SOCIETY OF AIME

by R. W. Shearman

Summary

The year 1960 was marked by an increased number of technical conferences and an increase in the number of pages of published literature. Attendance at 13 major conferences totaled approximately 8,000, with some 680 technical papers presented. Pages published in all media totaled over 5,300 pages.

Membership has also continued to grow, with a net increase of 544 members in 1960, giving a total of 8,309 corporate members. In addition, student membership numbers 547.

Staff Changes

The position of Associate Editor of JOURNAL OF METALS has now been filled by Edward Fitzgerald.

Following the resignation of R. M. Schelkopf as News Editor of JOURNAL OF METALS, William Leggitt has been appointed to this position.

Transactions

The number of pages of technical papers and notes published in TRANSACTIONS in 1960 was increased to 1131. A significant increase in material published by the Iron and Steel Division is noted in the following breakdown of papers published by the three divisions of The Metallurgical Society, comparing 1960 with 1959:

Div.	No. of Papers and Notes		Pages	
	1960	1959	1960	1959
EMD	16	20	82.25	89.00
IMD	184	186	881.75	873.00
ISD	28	14	167.00	102.00
	228	220	1131.00	1064.00

Following the practice established a year ago, the annual index has been included in the back of the December issue, giving an added service to readers.

With the October issue, preprints of their papers were made available to authors in advance of publication date of the issue. As this service entailed additional expense, it was necessary to end free distribution of reprints and to charge authors a nominal fee for preprints.

During 1960, Volume 215 (The Metallurgical Society) of AIME TRANSACTIONS was published. Volume 218, containing 1960 papers, will be ready early in 1961.

The budget for 1961 is based on the printing of 1152 pages in six issues of 192 pages each. It is anticipated that the total pages published in 1961 will actually be somewhat greater. Funds have been made available through a grant from the National Science Foundation to reduce the backlog of accepted but unpublished papers. However, through our own efforts, the size of the backlog was substantially lowered in 1960.

Journal of Metals

Every effort has been made, within our financial resources, to make JOURNAL OF METALS a more readable and more valuable periodical for the metallurgical profession. In addition to covering metallurgical developments on a national basis, coverage has also been given to major developments throughout the world. Through the technique of *special issues*, attention has been focused on new developments in oxygen steelmaking, non-ferrous extractive metallurgy, and electric furnace steelmaking. With other issues, JOURNAL OF METALS has tried to emphasize such important topics as: explosive forming, ductile iron, beryllium, fused-salt electrolysis, direct reduction of iron ore, titanium vs. steel, aluminum production in Africa and Australia, undergraduate metallurgy curricula, German and British research institutes, and the Navy's metallurgical research program.

The second annual salary survey of the metallurgical profession was published. More comprehensive data were made available, resulting from the use of an improved questionnaire.

The JOURNAL OF METALS has commenced the publication of critical reviews of new books in metallurgy and related fields written by well-known authorities in their particular areas of metallurgy.

A new expanded index lists the contents of the 1960 issues of the JOURNAL OF METALS. Appearing in the January 1961, issue, it contains additional subject classifications, a separate listing of authors, and for the first time a listing of authors' companies, a listing of Reporter items, and a listing of notices of new books and their authors. The 1960 index should be a great deal more useful than those of previous years.

During 1960, a total of 972 pages were published in JOURNAL OF METALS, contrasting with 860 pages in 1959. The breakdown between editorial and advertising is given below:

	1960	1959
Pages of editorial material:	772	671*
Pages of advertising:	236**	225**

* In addition, a Membership Directory of 90 pages was printed in the July 1959, issue.
** Including three advertising covers each month.

Non-member subscriptions to the JOURNAL OF METALS increased from a total of 2,013 in December 1959, to 2,203 in December 1960. This is reflected in the ever-increasing number of copies of the JOURNAL OF METALS being printed. The current print order as of December 31 was 11,800 copies, as compared with 11,400 a year ago.

Interscience Publications

Under terms of our agreement with Interscience Publishers, Inc., two additional volumes have been published in 1960 by Interscience Publishers and copyrighted by AIME:

Volume 5—*Properties of Elemental and Compound Semiconductors* (Conference sponsored by Semiconductor Committee of the Institute of Metals Division, and the Boston Section, AIME; Boston, August 31-September 2, 1959) 352 pages.

Volume 6—*Flat Rolled Products 2: Semi-Finished and Finished* (Conference sponsored by the Mechanical

(Continued on next page)

Secretary's Report

(Continued from preceding page)

Working Committee of the Iron and Steel Division, and the Chicago Section, AIME; Chicago, January 20, 1960) 160 pages.

In addition the following volume was also published by Interscience in 1960:

Extractive and Physical Metallurgy of Plutonium and Its Alloys (Symposium sponsored by the Nuclear Metallurgy Committee of the Institute of Metals Division, and the Titanium, Uranium, and Uncommon Metals Committee of the Extractive Metallurgy Division, and presented as part of the 1959 AIME Annual Meeting; San Francisco, February 16-17, 1959) 314 pages.

The following volumes are in preparation, and are expected to be published in 1961 by Interscience:

1. *Physical Chemistry of Process Metallurgy* (Conference sponsored by the Physical Chemistry of Steelmaking Committee of the Iron and Steel Division, the Physical Chemistry of Extractive Metallurgy Committee of the Extractive Metallurgy Division, and the Melting and Casting Committee of the Institute of Metals Division, and the Pittsburgh Section, AIME; Pittsburgh, April 27-30, 1959).
2. *Extractive Metallurgy of Copper, Nickel, and Cobalt* (International Symposium sponsored by the Extractive Metallurgy Division, and presented as part of the 1960 AIME Annual Meeting, New York, February 15-18, 1960).
3. *Refractory Metals* (Conference sponsored by the Refractory Metals Committee of the Institute of Metals Division, and the Detroit Section. AIME; Detroit, May 25-26, 1960).
4. *Metallurgy of Columbium* (Conference sponsored by The Metallurgical Society and the Hudson-Mohawk Section of AIME; Bolton Landing, N. Y., June 9-10, 1960).
5. *Powder Metallurgy* (International Conference sponsored jointly by the Metal Powder Industries Federation and the Powder Metallurgy Committee, Institute of Metals Division; New York, June 13-17, 1960).
6. *Response of Metals to High-Velocity Deformation* (Conference sponsored by the Physical Metallurgy Committee, Institute Metals Division; Estes Park, Colorado, July 11-12, 1960).
7. *Metallurgy of Elemental and Compound Semiconductors* (Conference sponsored by the Semiconductors Committee of the Institute of Metals Division, and the Boston Section, AIME; Boston, August 29-31, 1960).
8. *Decomposition of Austenite by Diffusional Processes* (Symposium sponsored by the Ferrous Metallurgy Committee of the Institute of Metals Division, and presented as part of the 1960 Fall Meeting of The Metallurgical Society; Philadelphia, October 17-20, 1960).

In addition, six Technical Conferences or Symposia will he held in 1961 that will result in proceedings to be published by Interscience Publishers.

Other Publications

The Institute of Metals Division published Volume 7 of the series on *Nuclear Metallurgy*. This volume comprised 12 papers presented at a symposium on "Metallic Moderators and Cladding Materials" during the Fall Meeting of The Metallurgical Society held in Philadelphia, October, 1960 (80 pages).

The National Open Hearth Steel Committee published Volume 42 of its Conference Proceedings (460 pages).

The Blast Furnace, Coke Oven, and Raw Materials Committee published Volume 18 (460 pages) and Volume 19 (788 pages) of its Conference Proceedings.

The Electric Furnace Committee published Volume 17 of its Conference Proceedings (576 pages).

The 16-page booklet, *Careers in Metallurgy and Metallurgical Engineering*, was published in September. Printing of 50,000 copies of this booklet was made possible through a grant of $7,500 from the National Science Foundation. Initial distribution of 25,000 copies was made through the packet service of the National Science Teachers Association. This has stimulated many requests for additional copies from guidance counselors and high school science teachers throughout the country.

Meetings

Technical Conferences of international significance were held during 1960 on these subjects:

1. Flat Rolled Products—Semi-Finished and Finished.
2. Refractory Metals.
3. Metallurgy of Columbium.
4. Powder Metallurgy.
5. Response of Metals to High-Velocity Deformation.
6. Metallurgy of Elemental and Compound Semiconductors.

Data on these conferences and others, 13 in all, are given in the accompanying table. During 1960, The Metallurgical Society and its technical committees presented a total of 687 papers at 129 technical sessions before an audience approximating 8,000. Not included in these statistics are the many technical meetings of local sections of AIME, and local sections of the National Open Hearth Steel Committee.

The Metallurgical Societv also participated in the annual Nuclear Congress, sponsored by Engineers Joint Council, and in the Annual Conference on Magnetism and Magnetic Materials, co-sponsored by several scientific societies.

The 1960 New England Regional

Technical Conferences and National Meetings of The Metallurgical Society, 1960

	Date & Place	Conference	Attendance	Number Technical Sessions	Number Papers Presented
1.	Jan. 20, Chicago	Mechanical Working	276	2	7
2.	Feb. 15-18, New York	AIME Annual Meeting (Met Soc)	1076	36	189
3.	Apr. 6-8, Chicago	43rd NOHC	1322	7	24
4.	Apr. 6-8, Chicago	19th Blast Furnace	707	9	36
5.	Apr. 20-22, Los Anegels	Acid Converter and Basic Oxygen Steel	41	3	5
6.	May 25-26, Detroit	Refractory Materials	400	4	17
7.	May 26-27, Boston	New England Regional	200	3	12
8.	June 9-10, Bolton Landing	Columbium	187	4	31
9.	June 13-15, New York	Powder Metallurgy	750	6	40
10.	July 11-12, Estes Park	High-Velocity Deformation	176	4	15
11.	Aug. 29-31, Boston	Semiconductors	540	5	33
12.	Oct. 17-20, Philadelphia	Fall Meeting	1277	37	231
13.	Nov. 30-Dec. 2, Chicago	18th Electric Furnace	1094	9	47
		Total:	8046	129	687

Conference was directly associated with The Metallurgical Society for the first time.

Plans were made in 1960 for these national technical conferences and regional meetings to be held in 1961, in which The Metallurgical Society will be concerned:

1. January 9-12, Symposium on Thermoelectric Energy Conversion, Statler-Hilton Hotel, Dallas, Texas.
2. **January 20, Third Mechanical Working Conference on Bar and Shaped Products, Penn-Sheraton Hotel, Pittsburgh.
3. February 26-March 2, AIME Annual Meeting, Ambassador and Chase-Park-Plaza Hotel, St. Louis.
4. *April 10-12, 44th National Open Hearth Steel Conference, Sheraton Hotel, Philadelphia.
5. *April 10-12, 20th Blast Furnace, Coke Oven, and Raw Materials Conference, Sheraton Hotel, Philadelphia.
6. **April 12-14, AIME International Symposium on Agglomeration, Sheraton Hotel, Philadelphia.
7. April 24-25, AIME Southwest Mineral Industry Conference, Stardust Hotel, Las Vegas, Nevada.
8. **April 26-27, Conference on High-Temperature Materials, Carter Hotel, Cleveland, Ohio.
9. May 18-19, 15th New England Regional Conference, Hotel Van Curler, Schenectady, N. Y.
10. **August 30-September 1, Third Technical Conference on Semiconductors, Ambassador Hotel, Los Angeles.
11. October 23-26, Fall Meeting of The Metallurgical Society of AIME, Pick-Fort Shelby Hotel, Detroit.
12. *December 6-8, 19th Electric Furnace Conference, Penn-Sheraton Hotel, Pittsburgh.

* Proceedings to be published through AIME.
** Proceedings to be published through Interscience Publishers, Inc.

Planning is underway for the visits of The Iron and Steel Institute of London to the United States, October 17-November 7, resulting from invitations issued by The Metallurgical Society and the American Society for Metals.

Of major importance is the plan to have The Metallurgical Society sponsor a series of conferences on Research Management in order to provide an activity of growing importance to a significant part of the Society's membership. Final plans have been made to hold the first conference on Management of Materials Research at Arden House, Harriman, New York, on May 17-18, 1961.

Membership

Membership statistics for The Metallurgical Society in 1960 are given in the following tabulation:

	Gain	Loss	Net	Total Membership as of December 31 1960	1959
ISD	309	97	212	2,881	2,669
EMD	200	47	153	1,360	1,207
IMD	288	167	121	2,815	2,694
Council of Education	1	19	(18)	22	40
Council of Economics	—	19	(19)	47	66
Unclassified	218	123	95	1,184	1,089
Total	1,016	472	544	8,309	7,765
Student Members				547	612
Total Corporate and Student Members				8,856	8,377

The net gain in corporate members during 1960 compares favorably with that recorded during 1959 and represents a continued improvement over earlier years. A reduction in staff time available for membership promotion of activities was offset by an extremely low loss through delinquency and resignations to sustain a net gain approximately equal to last year's. Although the use of successful techniques for gaining new members has been continued, it has not been possible to make as many visits to Student Chapters and Local Sections as would be desirable. It is hoped that this deficiency can be remedied during 1961.

The low loss and continued high gain figures can also be considered as an indication that efforts to expand and improve Society services are resulting in the retention of present members as well as the attraction of new members.

Acknowledgment

The contributions of the many members who served as officers of the Society or its Divisions and as committee members is gratefully acknowledged. Without their support, activities within The Metallurgical Society would not exist.

Thanks are due the many organizations who have encouraged their employees to take the time to participate in Society activities. Special thanks are due the industrial organizations that have continued their financial support to the Metals Research Publications Fund, thereby making possible the continued publication of all acceptable papers in metals research and engineering.

Recognition and thanks should be accorded the staff of The Metallurgical Society for their effective work in carrying through to completion the many projects of the Society.

Four Professors Become Honorary Members of Alpha Sigma Mu

Four university professors associated with the teaching of metallurgy have been elected into honorary membership in Alpha Sigma Mu, the honorary metallurgical fraternity. This action occurred at the Board of Trustees meeting on December 21, 1960. The new honorary members are: Prof. Ettore A. Peretti, University of Notre Dame; Prof. A. H. Larson, Missouri School of Mines and Metallurgy; Prof. George J. Fischer, Polytechnic Institute of Brooklyn; and Prof. Victor Franceschini, Polytechnic Institute of Brooklyn.

Alpha Sigma Mu was established in 1932 at Michigan College of Mining and Technology to recognize outstanding scholarship among students specializing in the arts and sciences of metals—hence the initials ASM. Present membership—about 1,000—includes students from approximately 25 schools which grant degrees in metallurgy. Chapters of the fraternity have been formed in eight of these schools, the most recent four in 1960 at Wayne State University, University of Maryland, New York University, and Polytechnic Institute of Brooklyn.

Blast Furnace Group Names Nominees

The Blast Furnace, Coke Oven, and Raw Materials Committee has nominated the following as officers for the coming year:

F. C. Anderko, Chairman

W. O. Bishop, Vice Chairman (two years)

D. C. Brown, Secretary

R. H. White and V. J. Nolan, Members Executive Board (four years)

Chairman of the Nominating Committee is Robert E. Powers.

NECROLOGY

Year Elected	Name	Date of Death
1929	Aamot, Olav Crone	Unknown
1928	Bean, Louis H.	Unknown
1909	Burchard, Ernest F. (Legion of Honor)	Feb. 2, 1961
1946	Finch, Lewis Jr.	Jan. 26, 1960
1941	Garbrecht, Louis	Feb. 12, 1961
1956	Giezentanner, Wm. L.	Sept. 29, 1960
1907	Knight, Cyril W. (Legion of Honor)	Oct. 13, 1960
1902	Leggat, Alex. (Legion of Honor)	January 1961
1939	Lynch, George E.	Nov. 30, 1960
1918	Putnam, W. P.	January 1961
1918	Richards, Ralph W.	Nov. 28, 1960
1955	Spangler, Brenner C.	January 1961

Coming Events

Apr. 10-12, 1961, 44th National Open Hearth Steel Conference and Blast Furnace, Coke Oven, and Raw Materials Conference, Sheraton Hotel, Philadelphia.

Apr. 12-14, 1961, AIME International Symposium on Agglomeration, Sheraton Hotel, Philadelphia.

Apr. 10-15, 1961, First International Congress on Metallic Corrosion, Imperial College of Science & Technology, London, England.

Apr. 13-15, 1961, Pacific Northwest Metals & Minerals Conference, Spokane, Wash.

Apr. 15, 1961, 13th Annual Spring Symposium, Indiana Chapters, American Society for Metals, Purdue University, West Lafayette, Ind.

Apr. 19, 1961, Western Section, NOHC, Dinner Meeting, Rodger Young Auditorium, Los Angeles.

Apr. 24-25, 1961, AIME Southwest Minerals Industry Conference, Stardust Hotel, Las Vegas, Nev.

Apr. 26-27, 1961, Cleveland Section and The Metallurgical Society, Technical Conference on High Temperature Materials, Hotel Carter, Cleveland.

May 17, 1961, Joint Meeting of Powder Metallurgy Group and Physical Metallurgy Group of the New York Section, Brass Rail Restaurant, New York.

May 17-19, 1961, The Metallurgical Society, Management of Materials Research Conference, Arden House, Harriman, N. Y.

May 18-19, 1961, AIME 15th New England Regional Conference, Hotel Van Curler, Schenectady, N. Y.

May 25, 1961, Cleveland Section, NOHC, Annual Golf Party, Wanakah Country Club, Hamburg, N. Y.

June 12, 1961, Pittsburgh Section, NOHC, Annual Golf Party, Mt. Lebanon Country Club.

June 14, 1961, Northern Ohio Section, NOHC, Annual Golf Party, Squaw Creek Country Club, Youngstown, Ohio.

June 17, 1961, Cleveland Section, NOHC, Annual Dinner Dance, Lake Shore Hotel, Cleveland.

Aug. 30-Sept. 1, 1961, AIME Third Technical Conference on Semiconductors, Ambassador Hotel, Los Angeles.

Aug. 31, 1961, Chicago Section, NOHC, Annual Golf Outing, Glenecagles Country Club.

Oct. 17-Nov. 7, 1961, Visit of the Iron & Steel Institute (United Kingdom) to the United States.

Oct. 23-26, 1961, Fall Meeting of The Metallurgical Society of AIME, Fick-Fort Shelby Hotel, Detroit.

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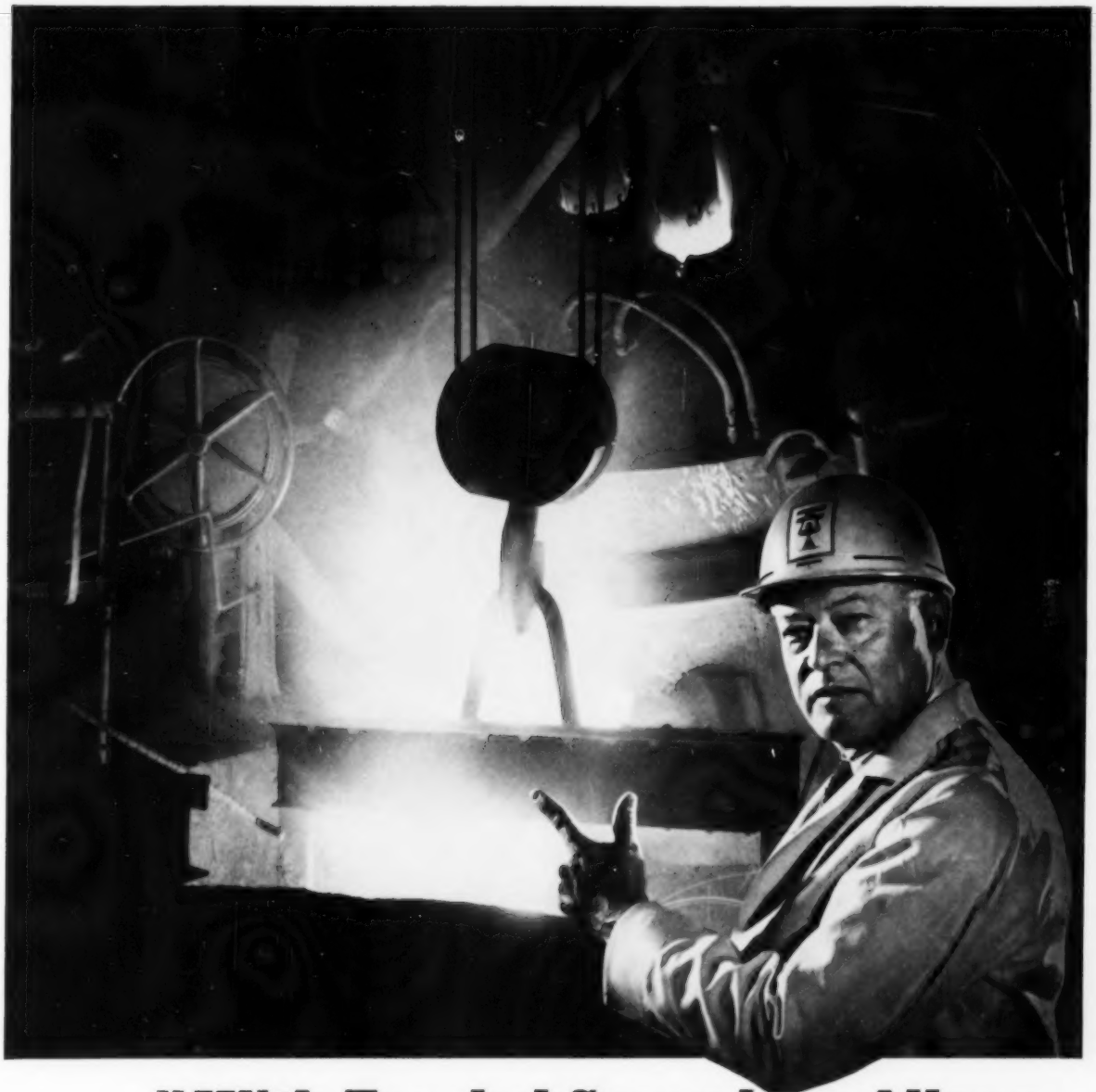

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